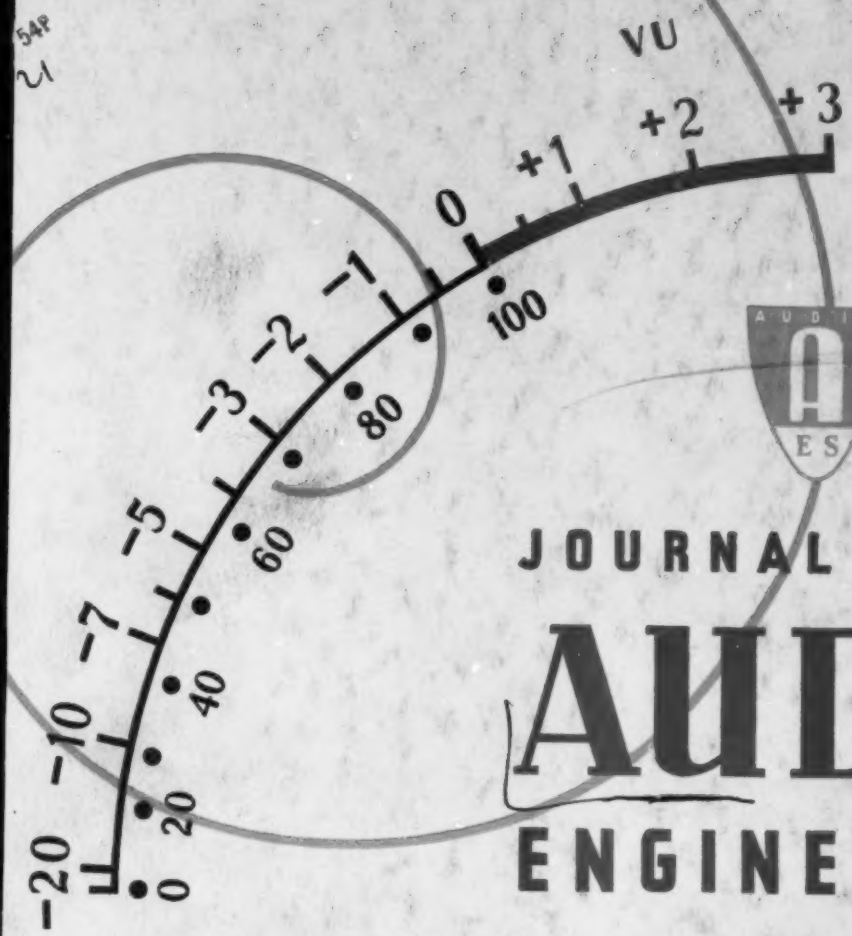


JOURNAL OF THE AUDIO ENGINEERING SOCIETY

VOLUME 2
NUMBER 1
JANUARY
1 9 5 4

JOURNAL OF THE AUDIO ENGINEERING SOCIETY

LEWIS S. GOODFRIEND, *Editor*

VINCENT SALMON, *Associate Editor*

VOLUME 2 • 1954 • NUMBERS 1-4

Journal of the AUDIO ENGINEERING SOCIETY

JANUARY 1954 VOLUME 2, NUMBER 1

OFFICERS FOR 1954

President
JERRY B. MINTER

Executive Vice-President
A. A. PULLEY

Central Vice-President
R. C. MOYER

Western Vice-President
BOYD MCKNIGHT

Treasurer
RALPH A. SCHLEGEL

Secretary
C. J. LEBEL

GOVERNORS

PRICE E. FISH — RICHARD H. RANGER
F. SUMNER HALL — C. R. SAWYER
JAY H. QUINN — LAURENCE J. SCULLY
W. O. STANTON

COMMITTEE CHAIRMEN

Admissions: PRICE E. FISH
Awards: F. SUMNER HALL
Constitution and By-Laws: V. J. LIEBLER
Convention: A. A. PULLEY
Cooperative Research: HUGH KNOWLES
Educational Standards: R. H. ROSE
Employment Register: C. G. MCPROUD
Finance: C. R. SAWYER
Historical: C. A. RACKEY
Lecture Course: JULIUS POSTAL
Membership: OLIVER READ
Nominations: LAURENCE SCULLY
Papers Procurement: AVERY LOCKNER
Publications: RICHARD H. RANGER
Public Relations: WALTER O. STANTON
Sections: C. J. LEBEL
Standards: W. H. OFFENHAUSER, JR.

Sections

Cincinnati — New York
Cleveland — San Francisco
Columbus — Southern Michigan
Los Angeles — Rensselaer Polytechnic Institute (student)

British Liaison

British Sound Recording Association
London W. C. 1, England

The AES Begins Its Seventh Year — *Jerry B. Minter* 1

The Proposed AES Disk Standard 3

Nomenclature for Motion Pictures and Television — *William H. Offenhauser, Jr.* 8

Nomenclature and the SMPTE — *William H. Offenhauser, Jr.* 12

Interim Committee on Nomenclature — *Calvin M. Hotchkiss* 14

Operation Nomenclature — *Julius Postal.* 17

Multichannel Sound Reproduction — *Walter T. Selsted* 20

A New Approach to Professional Magnetic Recording Equipment — *William F. Boylan and William E. Goldstandt* 25

System Design for Multiple Copying of Tape and Disk Program Material — *Robert D. Winston* 34

Some Notes on Problems Encountered in the Use of the Standard Reference Tape — *Frank Radocy* 36

The Compound Diffraction Projector — *Louis S. Hoodwin* 40

The Philosophy of Amplifier Equalization — *H. H. Scott* 45

The Significance of High-Frequency Intermodulation in Audio Equipment — *Emory Cook* 50

New Developments and Applications of Printed Circuits — *Arthur W. Kelly, Jr.* 52

High Fidelity — What Is It? 56

Book Review 58

AES News 59

Journal Authors 62

Editor: LEWIS S. GOODFRIEND
Associate Editor: VINCENT SALMON

The Journal of the Audio Engineering Society is published quarterly and supplied to all members of the Audio Engineering Society in good standing. Application blanks for membership and back numbers of the Journal may be obtained from the Secretary, P. O. Box 12, Old Chelsea Station, New York 11, New York.

Journal of the Audio Engineering Society, Volume 2, Number 1, January, 1954. Published quarterly by the Audio Engineering Society. Publication office, 104 Liberty Street, Utica, N. Y. Executive and editorial office, P. O. Box 12, Old Chelsea Station, New York 11, N. Y. Entered as second-class matter at the post office at Utica, N. Y. Subscription to nonmembers is $8 per year.

Copyright 1954 by the Audio Engineering Society.

SUSTAINING MEMBERS

Grateful thanks of the Audio Engineering Society are hereby extended to the following organizations which, as sustaining members of the Society, have made possible the undertaking of this publication. These organizations are:

ALTEC LANSING CORPORATION
AUDAK COMPANY
AUDIO DEVICES, INC.
AUDIO ENGINEERING
AUDIO & VIDEO PRODUCTS, INC.
BELL SOUND SYSTEMS, INC.
BRITISH INDUSTRIES CORPORATION
CAPITOL RECORDS, INC.
COLUMBIA RECORDS, INC.
COMPONENTS CORPORATION
THE DAVEN COMPANY
ELECTRO-VOICE, INC.
FISHER RADIO CORPORATION
GATES RADIO COMPANY
GOTHAM RECORDING CORPORATION
HARVEY RADIO COMPANY, INC.
HIGH-FIDELITY
MAGNECORD, INC.
McINTOSH LABORATORY, INC.
MEASUREMENTS CORPORATION
PERMOFLUX CORPORATION
PICKERING & COMPANY, INC.
PRESTO RECORDING CORPORATION
REEVES SOUND STUDIOS, INC.
REEVES SOUNDCRAFT CORPORATION
REGENCY DIVISION OF I.D.E.A., INC.
REK-O-KUT COMPANY
TERMINAL RADIO CORPORATION

Journal of the
AUDIO ENGINEERING SOCIETY

VOLUME 2 NUMBER 1

JANUARY 1954

The AES Begins Its Seventh Year

A Report by the President of the Audio Engineering Society

THE AUDIO Engineering Society was organized in February, 1948. The first meeting was held at the RCA Victor Recording Studios, 155 East 24th Street, New York City.

Since the founding of the Society, many of the original aims have been accomplished, but much remains to be done in the future. After six years of effort, it seems wise to pause and take stock of our current status.

Our Society was organized primarily to fill the need for promulgation of engineering information and standards in the field of recording, transmission, and reproduction of sound. For almost three years prior to the first meeting, Mr. C. J. LeBel, our first president, had discussed the proposed organization with many leaders in various audio fields. As a result of the combined efforts of Messrs. LeBel, Hall, Pickering, McProud, Colvin, Schlegel, Rackey, Stewart, Ranger, Pulley, and many others, the first meeting was arranged and the Audio Engineering Society became a reality by the end of the evening.

When the Society was founded, the Organizing Committee stated that the aims of the new professional society were:

"1. Develop technical and public appreciation of the importance of audio engineering as a *separate* profession with its own distinct background requirements.
2. Foster educational presentation of subjects basic to audio engineering.
3. Foster research on subjects basic to audio engineering.
4. Foster periodic audio engineering meetings. (It is proposed to start with five to seven meetings per year in each of two or three cities.)

JERRY B. MINTER, *President*, 1954

5. Provide facility for publication of papers on audio engineering.
6. Represent audio interests in the matter of engineering standards—before ASA, FCC, AMA, etc.
7. Possibly operate an employment register for qualified audio engineers, similar to that operated by the American Institute of Physics for physicists."

It is with some pride of achievement that members of

our Society can examine the above list and realize that each item has been accomplished. As an example, work toward the third item has been started through the adoption of the new AES playback curve published elsewhere in this issue (see page 3). All the major record manufacturers have examined their recording and processing techniques and endorsed this minor modification of our original AES curve published three years ago. A considerable number of man-hours have been spent in research and investigation of this new curve. The next logical step involves the making of standard AES test records and their sale to the industry. Thus the disk-recording industry has resolved its differences through the efforts of AES, and the public is the ultimate benefactor of our standard.

It is well known that many technical papers of interest to the audio field have been presented during our section meetings and annual conventions. Three lecture series have been sponsored in the New York section, and another series is announced elsewhere in this issue (see page 60). Thus we have accomplished item 4.

Item 5 has also become a reality. We have now started our second year of publication of the *Journal of the Audio Engineering Society*. This was made financially practicable through the generosity of our sustaining members in lieu of advertising in the *Journal*. Much credit is also due our able Editor, Lewis S. Goodfriend, the Associate Editor, Vincent Salmon, and the many contributors to the *Journal*.

During the growth of our Society from the original nucleus of 159 charter members to its present membership of over 1500, there has been a core of individuals whose consistent efforts have carried out and continue to implement the aims that were originally set forth. However, it is not enough to say that we are members of the Society; we must all contribute to its continued success by serving on its committees and aiding the Society's officers to expand both the membership and local section activities. Through active participation of more members, our Society can continue to expand and serve the rapidly growing field of audio engineering and the public in general who are rapidly awakening to higher standards in audio performance.

The Proposed AES Disk Standard

A Standard Playback Characteristic for Lateral Disk Recording

In presenting this proposal to the Society membership for trial and for comment, the Audio Engineering Society is following the best procedures laid out in broad outline by the American Standards Association, the national standardizing body for all technical standardization in the United States. The relationships between the ASA and its member bodies such as other technical societies (for example, the Institute of Radio Engineers and the Society of Motion Picture and Television Engineers), trade associations (such as the Radio Television Manufacturers Association), and individual companies that are directly concerned have been long established. In presenting standards proposals to our membership the Audio Engineering Society is preparing to take its place among all cooperating standards organizations within both the national sphere of the ASA and the international sphere of the International Standards Organization and related bodies through the ASA.

This tentative standard, AES TS-1, dated December 21, 1953, is published herewith for comment and three months' trial. Comments are invited from AES members and sustaining members, from members of other societies, from trade organizations, and from all other interested parties on any and all aspects of this standard and its use. Comments should be made in writing in as complete form as possible, addressed to the Chairman, Standards Committee, Audio Engineering Society, P. O. Box 12, Old Chelsea Station, New York 11, New York. These comments will be referred to the Chairman of the Task Group on Lateral Disk Recording so that all comments may be completely reconciled with the standard and referred by the Task Group to the Board of Governors through the Chairman of the Standards Committee. Comments are invited both on the content of this standard and on its format. All comments received will be given due consideration. The deadline for such comments is May 1, 1954.

In adopting this procedure the Audio Engineering Society establishes the precedent of giving the membership at large an opportunity to comment on standards before they are formally adopted and, subsequent to such adoption, recommended to the ASA for further action. It is the expressed wish of your President that each standard proposed for adoption by the Society shall receive widespread scrutiny to assure that the standard adopted is in the best interest of all parties concerned.

Reprints of this proposal are available at nominal cost through the Secretary of the Audio Engineering Society. *The Editor.*

Private Committee Document—not for re-publication

PROPOSED AES STANDARD

STANDARD PLAYBACK CHARACTERISTIC FOR LATERAL DISK RECORDINGS

(First Draft)

Reg. U. S. Pat. Off.
AES: TS-1
REV: AES-1951
December 21, 1953

1. Definition

1.1 Scope. The Audio Engineering Society playback characteristic describes the response-frequency characteristic of a system for the reproduction of lateral recordings exclusive of any equalization introduced as compensation for auditory or acoustic correction and/or individual preference. This characteristic is to be used with recordings cut at 33⅓, 45, and 78 rpm.

1.2 Curve Derivation. The characteristic curve is defined as the algebraic sum of the ordinates of three individual curves which conform to the impedances of the following networks expressed in decibels (db).

Curve I. A parallel combination of a resistor and capacitor having a time constant of 75 μsec. This curve provides high-frequency rolloff (–3 db at 2120 cps and –13.7 db at 10,000 cps).

Curve II. A series combination of a resistor and capacitor having a time constant of 318 μsec. This curve provides low-frequency boost, rising at the rate of 6 db per octave below a 500-cps crossover point (+3 db at 500 cps and +20 db at 50 cps).

Curve III. A parallel combination of a resistor and inductor having a time constant of 3180 μsec. This curve provides a very-low-frequency rolloff resulting in a departure of 3 db at 50 cps from the 6 db per octave slope of Curve II.

The curve, as described above and illustrated in the attached graphs, represents the desired amplifier output to be obtained when playing a constant-velocity frequency record.

2. Specification

2.1 Reference Point. Reference frequency is 1000 cps and for this standard is designated as a level of 0 db.

2.2 Response Tabulation. The response-frequency characteristic (referred to 0 db at 1000 cps) for constant velocity at the stylus tip is as follows:

Frequency, cps	Decibels	Frequency, cps	Decibels
30	+18.61	5,000	– 8.23
50	+16.96	6,000	– 9.62
70	+15.31	7,000	–10.85
100	+13.11	8,000	–11.91
200	+ 8.22	9,000	–12.88
300	+ 5.53	10,000	–13.75
400	+ 3.81	11,000	–14.55
700	+ 1.23	12,000	–15.28
1,000	0	13,000	–15.95
2,000	– 2.61	14,000	–16.64
3,000	– 4.76	15,000	–17.17
4,000	– 6.64		

It is recommended that reproducing equipment follow the curve and be attenuated smoothly beyond its limits.

2.3 Response beyond Limits of Specified Characteristic

2.3.1 Response above 15,000 cps. It is recommended that if extension of the high-frequency response is desired the high-frequency rolloff specified in 1.2 (Curve I) merely be continued as required.

2.4 Tolerance. To meet the Audio Engineering Society Standard, the maximum deviation of the system from this characteristic shall not exceed plus or minus 2 db.

2.4.1 In the event that the reproducing equipment has limited range it shall follow the curve insofar as possible and be smoothly attenuated beyond these limits.

3. Measurement

3.1 Equipment

a. Standard frequency record (AES No. 101*).

b. Indicating meter (the ASA standard VU meter, ASA specification 16.5-1942).

3.2 Procedure

3.2.1 The Audio Engineering Society standard frequency record shall be reproduced through the equipment under test and the output signal measured after record and reproducer compensation introduced for any other purpose.

* AES Standard Frequency Record No. 101 now in development (12-31-53).

NOT APPROVED

Audio Engineering Society, P. O. Box 12, Old Chelsea Station, New York 11, New York

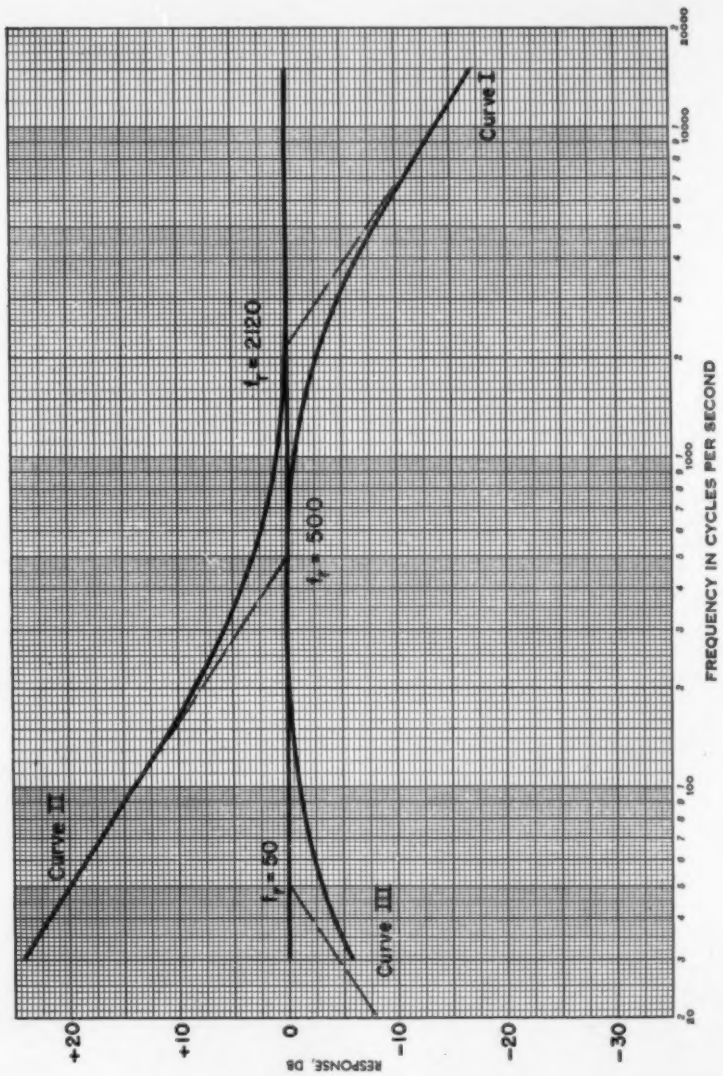
Private Committee Document—not for re-publication

PROPOSED AES STANDARD

STANDARD PLAYBACK CHARACTERISTIC FOR LATERAL DISK RECORDINGS

(First Draft)

Reg. U. S. Pat. Off.
AES: TS-1
REV: AES-1951
December 21, 1953



NOT APPROVED

Audio Engineering Society, P. O. Box 12, Old Chelsea Station, New York 11, New York

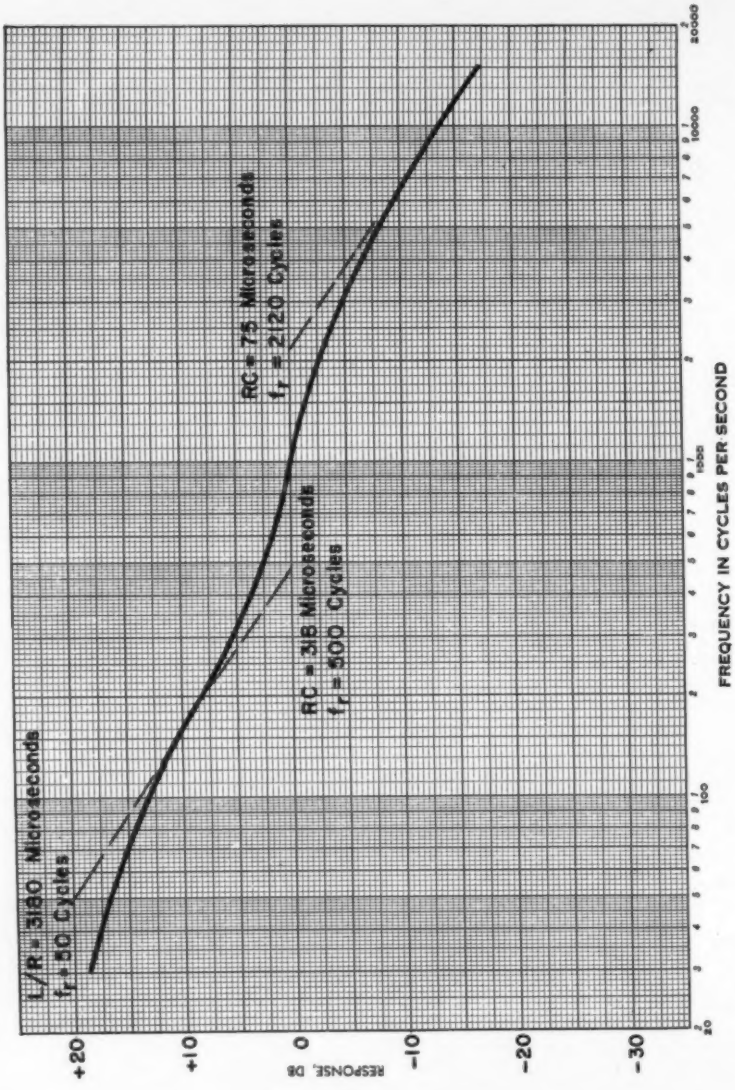
Private Committee Document—not for re-publication

PROPOSED AES STANDARD

STANDARD PLAYBACK CHARACTERISTIC FOR LATERAL DISK RECORDINGS

(First Draft)

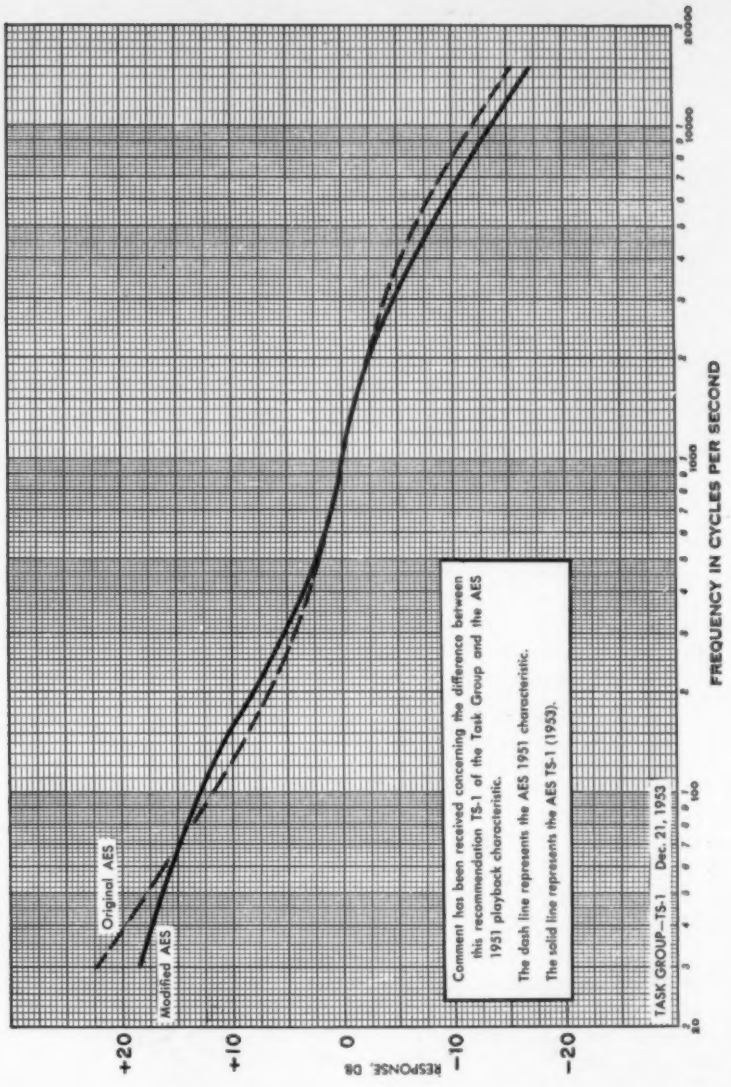
Reg. U. S. Pat. Off.
AES: TS-1
REV: AES-1951
December 21, 1953



NOT APPROVED

Audio Engineering Society, P. O. Box 12, Old Chelsea Station, New York 11, New York

NOTE: *This sheet is not part of the standard.*


Original AES
Modified AES
Comment has been received concerning the difference between this recommendation TS-1 of the Task Group and the AES 1951 playback characteristic.
The dash line represents the AES 1951 characteristic.
The solid line represents the AES TS-1 (1953).
TASK GROUP—TS-1 Dec. 21, 1953
+20
+10
0
−10
−20
RESPONSE, DB
FREQUENCY IN CYCLES PER SECOND

Nomenclature forms a very important part of every branch of science and engineering. Although the field of audio engineering has been professionally represented for the last six years by the Audio Engineering Society, little work has yet been done to organize its nomenclature. As a first step in this direction the following four papers presented before the Society of Motion Picture and Television Engineers are published.

Mr. Offenhauser is Chairman of the AES Standards Committee and has been successful in obtaining the cooperation of the Society of Motion Picture and Television Engineers and other organizations with the AES on matters of standards.

Nomenclature for Motion Pictures and Television*

WILLIAM H. OFFENHAUSER, JR.
Consultant, New Canaan, Connecticut

WHILE DISCUSSING the problems of editorial treatment of medical films, a friend once remarked that a particularly "sour" form of editing was "as dry as a page of logarithms." I have often wondered since just what the relative humidity of logarithms might be on the engineer's scale. In approaching the problem of nomenclature, I hope that the relative humidity of *this* subject will be at least 60% for this audience, a value of relative humidity found advantageous for the handling of motion picture film in a laboratory. Some of the developments now under way justify this optimistic view.

In recent years new ideas have been produced at an astounding rate; our progress is a direct result of our political concepts of freedom of speech and thought, and of the acceleration of progress by the free interplay of ideas through the voluntary associations of individuals with interests in common. Such individuals act as catalysts for one another in producing newer and better ideas; this occurs with every catalytic contact. With no artificial political restrictions, the catalytic contacts increase in frequency and effectiveness. The end result is as a summation of an infinite series of the expanding type, a result not obtainable in a society where the individual is told what he must believe.

The purpose of language is to convey ideas. Since the technical fields of motion pictures and television overlap and intertwine to the point where their interrelationships can not be successfully ignored, something has to be done to make it possible to interchange the ideas of one field with those of another.

To convey ideas, words are needed. As television, motion pictures, and related fields mature, the words required must become more and more specific in their meanings. To make possible the interchange of ideas within a particular group such as a technical society requires common nomenclature within that society. To make possible the interchange of ideas among different societies requires nomenclature common to the societies in question; technical standardization within the United States is accomplished through the American Standards Association (ASA). To make possible the interchange of ideas between groups speaking different languages (as in different countries of the world) requires nomenclature common to the groups; technical standardization on an international level is accomplished through the International Standards Organization.

Historically one of the biggest cultural steps accomplished in the United States was the publication of Webster's Dictionary. As Mark Twain said, "An argument arises when two persons use the same word to describe different things, or different words to describe the same thing." Although the conventional dictionary is an excellent guide to words, it is no longer adequate in specialized fields such as television and motion pictures because of the high order of specialization encountered in these fields.

The conventional dictionary must be supplemented with lists of specialized terms pertinent to and adequate for their specific fields of endeavor. When terms deal with concepts common to two or more fields, the terms must be further clarified to eliminate conflicts. This must be accomplished step by step, first at the local level, then at the national level, and finally at the international level.

The purpose of such specialized nomenclature lists is functionally the same as the purpose of the dictionary. Since we wish to convey ideas, it is but a small step in the process of inductive logic to arrive at the conclusion that the usefulness of a word diminishes when it acquires additional shades of meaning, and it is least useful when it acquires many unrelated meanings. The words "negative"

* Presented at the Semi-Annual Convention of the Society of Motion Picture and Television Engineers, Chicago, April 21, 1952.

and "positive" in our own motion picture nomenclature are representative examples; each one has four distinctly different meanings.

The Society for Motion Picture and Television Engineers (SMPTE) has only one American Standard Nomenclature formally approved at the national level. This is the American Standard Nomenclature for Motion Picture Film Used in Studios and Processing Laboratories, a list of a little over one hundred terms, which was approved on July 16, 1947, as ASA Z22.56-1947. No standard nomenclature for television has been approved at the national level despite the fact that television activities have already reached a commanding position in the SMPTE. This does not mean that the members have produced no nomenclature; it means merely that other channels of nomenclature development have been found more fruitful as measured by the numbers of terms approved per unit of time. Recognizing the importance of coordination and the magnitude of the job to be done, the SMPTE took the lead in setting up the intersociety coordination which is now known by the letters JCIC (Joint Committee for Intersociety Coordination). This project was begun by the Institute of Radio Engineers (IRE) and the SMPTE; these two societies were soon joined by the Radio Television Manufacturers Association (RTMA). Finding that others were interested, the committee broadened its scope and changed its name to that just given; this occurred when the National Association of Radio and Television Broadcasters (NARTB) became an active participant. There is little doubt *now* that the fields of television and motion pictures are merging, are, indeed, permanently joined, and that their problems of nomenclature will be solved by a mutual effort.

The IRE has established a master index of IRE definitions. Since definitions must be composed before they enter the master index, the IRE has established twenty-three main committees averaging about fifteen men each and eighty-five subcommittees averaging ten men each to produce the required material—over one thousand people engaged in the job of furnishing nomenclature for the Institute's activities.[1]

What is a definition, and how does it apply to the terms we use? To quote Webster's New International Dictionary, a definition is the "act or process of explaining the meaning or meanings of a word, term or designation; esp., the act or process of distinguishing such meaning or meanings from those of synonyms, correlatives, opposites, or the like; also a formulation of such meaning or meanings; as, dictionary definition."

In addition to telling what a definition is, we may also specify and describe what it is not. The selected term and its definition should not be jargon. The dictionary defines jargon as "barbarous or debased language." In a lecture on the art of writing, given at Cambridge in 1916, Sir Arthur Quiller-Couch described jargon as "a kind of writing, which from a superficial likeness, commonly passes for prose in these days, and by lazy folk is commonly written for prose, yet actually is not prose at all." He added that the two main vices of jargon are that (1) it uses circumlocution rather than short straight speech, and (2) it habitually chooses vague, woolly abstract nouns rather than concrete ones. Jargon is an "infirmity of speech," and it renders much technical writing ridiculous. It deals in paraphrases instead of going straight to the point; it loves the abstract rather than the concrete; it dabbles in words of sound rather than of meaning.

The SMPTE has no master index of definitions, and it has never sent a definition to the IRE to be included in its master index, nor has the SMPTE asked the IRE to provide its members with a definition. If we are not to produce a master index of our own (and it seems wise that we should not because we would merely duplicate work already under way in other agencies), it is desirable for us to exchange terms formally with the IRE by furnishing lists of what terms we have and receiving terms that IRE has produced. In this way the interrelationship between television and the motion pictures will be further strengthened.

The SMPTE can contribute considerably to the common nomenclature index. Among the contributions especially commended is the remarkable glossary list produced by John M. Andreas. His "Glossary of Terms," which was submitted to the SMPTE Committee on Standards in November, 1942, is an invaluable contribution that is practically unknown to most of our members. No formal action was ever taken to adopt or to use this most significant contribution. This oversight should be corrected, and the Glossary should be carefully reviewed and then sent to the IRE to be entered in their master index. There are other products of individual initiative without benefit of formal directive. Some of these include:

"400 Terms Used in Production of 16-Mm Non-Commercial Motion Pictures," produced within the University Film Producers Association.

"Glossary of Motion Picture Terms," a mimeographed collection of terms compiled by the Academy of Motion Picture Arts and Sciences.

"The Glossary," compiled by the Theater Arts Department of the University of California at Los Angeles.

"The Glossary," listed by Raymond Spottiswoode in his book, *Film and Its Techniques* (this book is also a noteworthy contribution).

Either the IRE or the SMPTE should take the step of reviewing the *"TV Dictionary/Handbook for Sponsors"* compiled by Herbert True for *Sponsor* magazine. Engineers

[1] The figures given are approximate; some of the subcommittees are being recast.

must admit—after reading it—that the advertising people have been coining terms of their own to describe processes for which the engineers are responsible. If we don't like some of their definitions—and there are many that could not possibly be accepted by the American Standards Association—we can blame only ourselves for having failed to provide adequate nomenclature. As the copywriters say, "A handle is a very useful thing." A copywriter never tries to lift a clumsy package without at least one sturdy, convenient handle. Engineers need "handles" too.

Let us suppose that we have collected several lists of terms from a variety of sources; what do we do next? First, the relative importance of the various definitions must be determined; this is accomplished by use. Some time ago technical groups interested in color were faced with just that problem, and they formed the Inter-Society Color Council (ISCC). The ISCC set up a cooperative project of the member societies that included the ISCC Subcommittee on Color Terms with the aim of clarifying the identities, the similarities, and the differences inherent in the uses of the terms within the different societies. This was accomplished by listing all terms submitted, and the terms were keyed with respect to source. From this compiled list, any reader may determine:

1. The meaning of a term for a given society or source.
2. What societies have an identical definition of that term and hence generally unquestioned agreement with respect to it.
3. What societies have similar definitions of the term and hence a basis for developing agreement.
4. What societies have quite different usages for the term and hence the special need to guard against confusion.
5. What societies use a different term or terms with a similar meaning.[2]

Many may be surprised to learn that the SMPTE is a very active member of the ISCC. You may also be pleased to learn that three years' use of the ISCC Comparative List of Color Terms (the list was published in January, 1949) has resulted in clarification to the point where a significant body of terms is almost ready for ASA standardization.[3]

Let us assume now that a group of terms has been accepted by the ASA. What is the next step? One destination is the International Electrotechnical Commission's Advisory Committee No. 1 on Nomenclature. In document RM-205 are found the minutes (unconfirmed) of the meeting held at Stresa on June 16-18, 1949, under the chairmanship of General E. E. Wiener of Belgium, with Mr. C. Dietch of France as secretary.[4] At the international level, the following countries and organizations take an active part: Austria, Belgium, Denmark, France, Italy, the Netherlands, Norway, Poland, Sweden, Switzerland, the United Kingdom, the United States, the International Scientific Union (URSI), and the IEC Central Office.

The original text of definitions is drawn up in both English and French, and each group of definitions is allotted to subcommittees consisting of experts drawn from a single country. The subcommittees, known as drafting subcommittees, are to be appointed by the National Committee to whom the preliminary work corresponding to a given group has been allotted. The preliminary work includes the subdivision of the group into sections, the drawing up of a list of terms in each section, the choice of the order in which the terms of a given section appear, and the drafting of a definition for each term. The drafting subcommittees are to take account of the decisions reached by Advisory Committee No. 1 and recorded in the minutes and to forward to the Secretariat a complete text for the group allotted to them. They will have the power to enlist as necessary the aid of experts from neighboring countries or those especially well qualified or belonging to national organizations representing international organizations with which collaboration is envisaged.

The following are a few of the assignments appearing on the work assignment list for nomenclature in the IEC Advisory Committee No. 1 on Nomenclature:

Subject	*Chairman*
Fundamental definitions	France
Apparatus for scientific industrial measurement	France
Illumination	Netherlands
Electrochemistry	United States
Electronics	United States
Electroacoustics	Italy
Servomechanisms	United Kingdom

Now that the serious aspects of the problem of nomenclature have been considered, let us see the more humorous side, as shown by a few definitions from the *TV Dictionary/Handbook for Sponsors*:

Fish bowl—the client's observation booth with TV monitors.

Fish him out—slang for send the boom down to pick up sound, but don't get boom or mike in picture.

Flack—the publicity writer for TV talent, show, etc.

---

[2] This list is available to members of the ISCC at a price of $1.00 and to nonmembers at $2.00. Anyone interested in nomenclature cannot afford to be without it; it is also a must for anyone interested in color. Copies may be ordered (with remittance) from the Inter-Society Color Council, P.O. Box 155, Benjamin Franklin Station, Washington 4, D. C. There is no staff available to handle correspondence.

[3] These terms were approved by the Illuminating Engineering Society and routed through the IRE to the American Standards Association. Although members have taken an active part in the approval procedure, the SMPTE has not been a channel for routing these definitions to the ASA.

[4] Available from the Central Office of the General Secretary of the IEC at 39, Route de Malagnou, Geneva, Switzerland. The minutes are available in English and in French, as these are the official languages.

Gizmo—(generic term) something for which a more technical definition is lacking or has been forgotten altogether by the speaker.

Hassel—complete state of flux, everything going wrong.

Haywire—temporary equipment, or equipment in poor condition.

Hiatus—the summer period, usually eight weeks, during which a sponsor and/or talent may discontinue his program, but thereafter resume his time period or show until the next hiatus.

Hitch-hike—an isolated commercial for one of the sponsor's products (not advertised in the main body of the show) which is given a free ride after the end of the program proper.

Hog-calling contest—a strenuous commercial audition for talent or announcers possessing special qualities, plus a good voice.

Hypo—to add vitality and interest to a program by changing its format, cast, agency, producer, writer, or, sometimes, its sponsor.

Jam—High-pressure selling talk on a TV commercial.

Lock-jaw—(1) a tired, uninspiring, lifeless singer; (2) talent who speaks with little or no facial expressions.

Squeak stick—Clarinet player.

Zilch—Standard name used to describe anyone who walks into TV studio and whose name is not known.

To quote Oliver Wendell Holmes: "There is a fascination in the mere sound of articulated breath; of consonants that resist with the firmness of a maid of honor, or half or wholly yield to the lips; of vowels that flow and murmur, each after its kind; the peremptory b and p, the brittle k, the vibrating r, the insinuating s, the feathery f, the velvety v, the bell-voiced m, the tranquil broad a, the penetrating e, the cooing u, the emotional o, and the beautiful combinations of alternate rock and stream, as it were, that they give to the rippling flow of speech—there is a fascination in the skillful handling of these, which the great poets and even prose writers have not disdained to acknowledge and use to recommend their thought."

Nomenclature and the SMPTE*

WILLIAM H. OFFENHAUSER, JR.
Consultant, New Canaan, Connecticut

THERE HAVE been rumors recently of nomenclature activity within the SMPTE. I can now confirm that this is true and also that the cooperation of all members is needed. Those who are interested should write to the Society offices. Please specify the area of your activities so that we may refer you to the Nomenclature representative of the Engineering Committee concerned, and please mention the Nomenclature Committee. Remember, also, that symbols and abbreviations are extremely important parts of nomenclature.

Why did this start? To quote Terry Ramsaye (*Motion Picture Herald*, August 2, 1952), in an article called "Jungle Jargon":

> A side effect of the swiftly evolving technology of the motion picture, radio, television and color fields is a terrific interindustry and international problem of words and standardized names for things, so that workers of the electronic world can understand one another . . .

For a number of years many members of the SMPTE have been acutely aware of this pressing problem and have been trying to do something about it. Several attempts were made just before World War II; a few almost succeeded. The glossaries published by the SMPTE before 1945 show that much serious work was being done. At the national level nothing happened until 1945—during the war—when a mere one hundred terms were approved. Nothing has been approved since.

After 1947, despite the rapid production of new ideas and concepts and new apparatus of all kinds as well as new techniques for using it, the actual development of much of the corresponding nomenclature was assumed to be the responsibility of the advertising agency people who needed words suitable for describing their daily work and the equipment with which it was accomplished. Engineers seemingly had neither the energy nor direction to do the job. It was not long before this serious state became apparent to any critical reader of the SMPTE *Journal*. Collections of terms began to appear, but to a great extent these consisted of what Terry Ramsaye has so aptly called "jungle jargon."

Other societies meanwhile made progress. In chemical, electrical engineering, and radio fields, for example, an outpouring of terms occurred, almost all of which acquired quick acceptance. When this situation was brought to the attention of the SMPTE membership in the Spring Convention of 1952, Joseph Kaselow wrote in his column, "The Advertising Field," in the *New York Herald Tribune* of May 2, 1952:

> The TV engineers are going to try to reclaim their language from the ad agency boys who, they seem to feel, are treating it a bit cavalierly. They figure they started the stuff so why shouldn't they have the right to name it. It has been admitted by one of these engineers that the terminology being used by the ad people in radio-TV has value in certain instances, but such jargon has a short life and should be *replaced* by exact terms for technical use. The agency people have been coining words to describe processes for which the engineers are responsible. We hope for the best, but we've covered too many sessions of TV engineers to expect it. You know those engineers. They're wonderful guys—but they like to say what they mean even if nobody can understand them.

If this story has a moral, it is that we should coin terms *ourselves* if we don't like those produced by others. Here are some samples that we might replace:[1]

Cans—receivers and head phones worn by cameramen, stage manager, technical director, etc., in the studio, and engineers on remote.

Crack a lens—cover a portion of the picture with the lens turret.

Straight up—TV show is on the nose—timed perfectly.

Gizmo—(generic term) something for which a more technical definition is lacking or has been forgotten altogether by the speaker.

The last term has an inversion or reciprocal. Spelled backward, this term becomes omzig. In formal presentation it appears as follows:

Omzig—an inverted gizmo—in video decoding, something for which a technical definition is neither lacking nor has it been forgotten by the speaker; he is merely ashamed to use it as a term. (Credit: H. E. White and C. M. Hotchkiss of Eastman Kodak).

Since sound motion pictures and television had a common origin in a young scientific art once called electricity but now called by the more euphonious term electronics, it is no surprise that engineers have shifted back and forth between television and motion pictures as the needs of commerce have dictated. Although the nomenclatures of the two fields developed separately, the slower growing but large perimeter of the motion picture field has already been dented by the faster inflating perimeter of television. Nomenclature has already crossed weakened barriers which are showing more and more evidence of complete breakdown. From the standpoint of the physicist-engineer, these barriers are entirely artificial and are doomed, as are all such arbitrary restrictions placed in the path of scientific growth and development.

* Presented at the 73rd Semi-Annual Convention of the Society of Motion Picture and Television Engineers, Los Angeles, May 1, 1953, as part of the Progress Report of the Interim Committee on Nomenclature of the SMPTE.

[1] Other examples appear on pp. 10-11.

Technologic overlaps between motion pictures and television are inevitable. Today the kinescope recordings of television consume more film than do the strictly professional motion pictures, and educational television will increase this consumption. With regard to color television, no prediction can be made except further increase.

New concepts are being produced every day, and new words and new symbols are being *sought* to identify and describe them. Consider, for example, the new commercial frontiers facing this industry: 3-dimensional processes, panoram processes (such as Cinerama), wide-screen processes of other kinds, television commercial spot announcements using electronically operated puppets, new methods for animated cartoons going even beyond those by George Pal, and color television systems, theater television systems, magnetic video recording, etc. This list can easily be enlarged with stereo and multichannel sound.

Nomenclature will be manufactured and is, in fact, being manufactured all the time. Let us therefore recognize our position as the group in the country responsible for the state of *our* nomenclature now, as well as in the future. New terms will occur; it is our duty to deal with them and to help the pioneers provide an orderly growth.

In a paper[2] presented at the Semi-Annual Convention of the SMPTE in April, 1952, the need for a suitable nomenclature and the early efforts of the various societies, including the development of the IRE master index, was discussed. Since then, the NTSC,[3] now preparing its new system of color television called acuity-matching for presentation to the Federal Communications Commission, has also recognized the need for an accurate system of nomenclature to describe the concepts and the characteristics of its color system. A nomenclature panel known as NTSC Panel 19 was formed, consisting of engineers who were qualified not only by their first-hand participation in the engineering development of the system but also by their past experience in producing functionally correct and accurate terms and definitions for the various engineering concepts. The work of this panel is completed, and an atmosphere of effective teamwork, efficiency, good will, and common sense pervaded every meeting. Our observers have participated in these meetings; we consider them a model by which other activities such as our own may be guided.

The same encouraging conclusions are reached when the accomplishments of other nomenclature groups sponsored by such organizations as the ASA, the NARTB, and the OSA are examined. When the Interim Committee on Nomenclature was organized recently, the advice and constructive criticism of the chairmen and members of these other nomenclature groups was requested. It has been freely and gladly given. The committee has kept in constant touch with these other society groups and has established a working system of interchange of ideas, of progress reports, and of lists of terms and definitions. Since the scope of the SMPTE embraces not only motion picture engineering and the use of motion picture films and equipment in television but also the various fields of television itself and other fields that are directly related to motion pictures and television, the aim of this committee has been to compile and collate existing terms and definitions from all such sources and to produce new terms and definitions for existing concepts and for new concepts as they evolve.

The story of the organization and growth of the committee, of its present accomplishments, and of its aims and goals will be described in the paper by Mr. Hotchkiss, which follows.

---

[2] See the paper by Mr. Offenhauser on p. 8.

[3] Since this paper was prepared, the FCC has approved the compatible color television engineering recommendations of the National Television Systems Committee.

Interim Committee on Nomenclature*

CALVIN M. HOTCHKISS
Motion Picture Film Department, Eastman Kodak Company, New York, New York

MR. OFFENHAUSER, Chairman of the Interim Committee on Nomenclature, has asked me, as Committee Secretary, to prepare a brief review of its organization, activities, and positive accomplishments to date. Before we tell you of what we hope to accomplish in the near future, you should have a clear idea as to what had actually been done with nomenclature before the organization of the Interim Committee, and what has been accomplished since it started last fall.

Early in the spring of 1941, a Nomenclature Committee under the editorship of Mr. Sylvan Harris was formed. During the period from May, 1941, until February, 1942, this committee, which numbered fifteen SMPE members, produced definitions for 520 motion picture engineering terms. Many of these terms had to do with photographic systems or processes, the majority of which were only of historical interest since they had long been obsolete. Others defined patented and current processes. Still other terms and definitions involved the use of brand names and trademarks. Although the Harris glossary was submitted to the Standards Committee for approval in February, 1942, no action was taken by the board. The suggestion was made by the Standards Committee that the work be reviewed to revise many terms and definitions. Dr. John M. Andreas of the Technicolor Corporation was asked to undertake this laborious job, and he accepted. In the fall of 1942, Dr. Andreas submitted the revised version of the glossary to the Standards Committee for review, the committee approved it, and it was then copy edited and reproduced by mimeograph for distribution to the members. Although Dr. Andreas' work unfortunately never received the attention it deserves, there are still quite a few copies in active use. This work is an excellent reference for defining many current as well as historical terms in motion picture film matters.

With a view to expanding the 1942 glossary and bringing parts of it up to date, a Nomenclature Committee was formed in August, 1944, numbering fifteen SMPE members, under the chairmanship of Mr. F. T. Bowditch. Three members of this group, incidentally, represented the SMPE as one of the twenty-nine organizations in the ASA Sectional Committee Z22, which was responsible for the production of the 109 terms and definitions to be found in Z22.56-1947, referred to by Mr. Offenhauser in his paper. It was the intent of this group first to review the 1942 glossary for possible modifications, deletions, or additions, and to present a revised edition of the glossary to the Standards Committee for approval and publication under SMPE sponsorship. Although the work was begun with fervor (and certainly much was accomplished in the period from August to October, 1944), the work of the committee seemed to meet with serious opposition on the part of some members. In the presence of this discouraging atmosphere, the work that was so well begun petered out completely. From that time until last summer, the nomenclature files in the New York office did little but gather dust. One day toward the end of the summer, a few of us pulled all the nomenclature material out of the files and dusted it off. We had the blessing of the Engineering Vice-President when we did this, by the way. I will tell you more about these files later on.

Since the first order of business on the part of the Interim Committee Officers was to form a Coordinating Committee composed of representatives of the SMPTE Engineering Committees, we looked for the practical and successful methods used by others in the past. We talked with Mr. M. W. Baldwin, Jr., Chairman of the Definitions Coordinating Subcommittee of the IRE, and also with Mr. E. K. Gannett, IRE Technical Editor, asking for advice and suggestions based on their successful experience with (1) the organization of a nomenclature committee and its task groups and (2) the production, editing, publication, and distribution of nomenclature material. Mr. Offenhauser has already referred to the IRE system of nomenclature production. We have adhered to the basic operating principles used by that organization. Its methods and principles appear to require no changes, if our experience to this point may be used as a guide.

The second order of business was to collect and compile all existing nomenclature material and to set it up in the committee workbooks. An inventory was made of all material available from the SMPTE files and reviewed for acceptance or elimination from the workbooks. Acceptance or rejection depends on its present use or its obsolescence; much material has been replaced by more recent sets of approved nomenclature. Among this collection are the 1942 glossary of the SMPE, some IRE Standards on Definitions,

* Presented at the 73rd Semi-Annual Convention of the Society of Motion Picture and Television Engineers, Los Angeles, May 1, 1953, as part of the Progress Report of the Interim Committee on Nomenclature of the SMPTE.

and a number of glossaries produced in the past years by other societies or organizations such as the University Film Producers Association and the NARB. Each term was assigned one page in the workbooks, and every existing definition for that term was placed on that page. Suggestions received from committee members and others regarding modification, revision, or deletion of the term and its definition from the working list are immediately recorded on the appropriate page, with the source and date of receipt of the proposal. In this manner, a complete history of the production of a term and its definitions becomes a permanent record for future reference.

The organization of the Interim Committee was the next job. Individual letters were sent out to the chairman of each Engineering Committee in the SMPTE, requesting that he appoint a man to represent his committee on the Nomenclature Committee. As the appointments were made, new committee members were asked to form task groups of their own choosing, made up of individuals who were qualified in the specialized field represented and who were *interested* in the production of nomenclature for their respective fields; task group personnel need not be members of the SMPTE. The principle underlying such organization is clear: the production of nomenclature originates with a qualified group of men who represent a specific field in diversified branches of the industry. Only in this way can a term and its definition receive proper study during the period of its formulation. A finished term and its definition can then be considered to possess authoritative and responsible character.

To assure acceptance of a finished term, we must be certain that there has been an effective interchange of concepts with others outside the SMPTE. The next step in organization was therefore to invite people outside the SMPTE to take part in committee activities. The present mailing list for committee memoranda, which contain work in progress as well as future work proposals, now has the names of fifteen people who are not members. A *mutual* exchange of work material on nomenclature has been set up between the SMPTE Interim Committee and the IRE, NTSC, ASA, NARTB, and various individuals belonging to companies and organizations in the motion picture and television industry. This list, which represents a rapid interchange of ideas and material on the national level, is continually expanding as awareness of what we are attempting to accomplish spreads. In addition to our own committee membership and some people outside the SMPTE, the list now contains the names of those whom we have invited to participate as individuals on the international level. Although the work of this third group cannot begin formally until a substantial amount of nomenclature material has become approved and accepted at the national level, active work has already begun in the preparation of foreign language equivalent terms for a number of definitions already approved and published by the ASA in the fields related to motion picture engineering and motion picture film use in television. This third group already includes individuals who are in the National Film Board of Canada, a Canadian television broadcasting and equipment manufacturing company, several French companies in the motion picture and television fields, the Telecommunications Group of the United Nations, and still other individuals connected with motion picture and television operations in several European countries. Additional invitations have been sent to people in England and France. Other nationalities that we hope to have with us are Italian, German, and Spanish. All these people have one common interest: proper nomenclature for motion pictures and television.

During the past few months, collating existing material has demanded much attention and time. The ASA Standard Z22.56-1947 has been reviewed by the committee for possible revision and modification, and nomenclature from other ASA, IRE, and NARTB standards has been reviewed for acceptance in the working list. The most recent committee work consists in the production of revised or entirely new definitions for existing terms. A number of sources have been used for reference material in the production of these definitions, and in every case these sources have been chosen from widely accepted and widely used publications. Wherever possible, new definitions have been produced directly from approved standards. Where none exists, other good source material, such as Spottiswoode's Glossary in *Film and Its Techniques*, published in 1951, has been used. Each definition is being set up in accordance with standard dictionary format. This indicates the part of speech, synonyms, and any colloquial terms. In addition, the defined term is codified according to a proposed scope of categories, and upon approval by the Interim Committee receives an acceptance classification and is placed in its proper category in the workbooks. When a substantial number of defined terms in a particular section have been so accepted, the section as a whole will then be submitted to the Standards Committee for approval. Modifications requested will be incorporated by the Committee Secretary, and the completed section will then be printed and distributed to SMPTE members. These published sections of the glossary will remain open for later revisions or additions as the members have the opportunity to study the entries and comment on them. Incidentally, this follows NTSC Panel 19 procedures.

The Interim Committee will continue to produce definitions for any additional terms that may be proposed from time to time for addition to the sections. In this way, sections of the glossary may be submitted for approval and publication as soon as they attain substantial size and worth. The SMPTE will not have to wait until final completion of

the entire glossary before accepted definitions can be distributed and used. It is contemplated that, after a particular section has been distributed and studied by the members and a certain amount of time has been allowed for the receipt of suggestions and criticism, the section may then be submitted to the ASA for study and approval. (This, by the way, follows IRE procedure.)

In general, the glossary now embraces three broad categories: motion picture engineering, magnetic recording of picture and sound information, and television engineering. These have been broken down into the various phases such as manufacturing terms, equipment terms, and terms related to applied practice and use of vehicles and equipment. At present the workbooks contain over 1500 terms and, of course, many more definitions applying to these terms. Approximately 800 of these are from authoritative sources such as the ASA or IRE standards material; approximately 600 are at present being submitted with proposed definitions to the Interim Committee for study and comments. The remaining terms have no existing definitions which are acceptable from the point of view of good nomenclature or engineering practice; these terms will be submitted in the near future to committee members for defining by the task group and editing by the task group head. By the end of June [1953], several sections of the glossary should be ready for final editing before presentation to the Standards Committee. By the end of the year, a substantial number of sections should have been submitted and reviewed for acceptance. The entire section on motion picture engineering should be completed by the end of the year, and certainly the major portion of the other sections dealing with recording and television should have been completed by this time.

Mr. Offenhauser has told you why the Interim Committee was formed and has given you a general review of the operating principles involved in preparing its organization. His report has been followed by a detailed description of what has been accomplished to date by the Interim Committee and what we expect to accomplish in the future.

The next paper, prepared by Mr. Julius Postal, will describe the working philosophy underlying nomenclature production. This philosophy is based on the individual and group experience of nomenclature activities and has been prepared for presentation from the numerous comments and reflections of many people who have served at one time or are still actively participating in committees such as Panel 19 of the NTSC, the definitions committees of the IRE, the NARTB, the AES, the AIEE, the ASA, and allied organizations. It is this philosophy which has given us all the inspiration to take up the torch from where it was extended by tired and exhausted hands; it is this philosophy which we hope will stir others in the SMPTE to become interested in what we have done and in what we hope to accomplish.

Operation Nomenclature*

JULIUS POSTAL
Tele-Science Production, New York, New York

MANY A TIME in the history of this or that human culture, whenever a particular thing or activity has been very important to the people living in that culture, they have invented a host of very specific terms to differentiate fine shades of meaning. This information was neatly set forth on a recent radio program.[1]

For example, snow is much too important to an Eskimo to be dismissed with just a single word. The Eskimo has many words describing particular kinds of snow, words telling not only what kind of snow it is, but when it fell, whether it is loosely packed or tightly packed, and so on. To an Eskimo, snow—that is, *exact* knowledge of its condition—is literally a matter of life and death. And a certain group of California Indians places a very high value on woodpecker scalps and obsidian blades. In addition to the ordinary set of numerals, they have two extra sets of numerals, one for counting woodpecker scalps and another for counting obsidian blades.

A few hundred years ago, the people of England relied to a great extent on hunting for their means of subsistence. When they carved their game birds on the dinner table, they didn't just "cut them up." They had some very specific terminology to describe the job: A heron was "dismembered," a mallard was "unbraced," and a pheasant was "allayed." A partridge, on the other hand, was "winged," a quail was "displayed," a goose was "reared," and a curlew was "unlatched"! As the technology of obtaining food changed, this nomenclature passed into the limbo.

Why bring all this up? Consider, for example, the motion picture industry, where the word "negative" has been applied on various occasions to half a dozen different *kinds* of negative, such as sound track "negatives," which are actually recorded on *positive*-type emulsions. Neither the Eskimos, nor the California Indians, and certainly not the Englishmen of the Elizabethan period would have tolerated a nomenclature situation like that!

Obviously, there are quite a few things we can learn from other peoples. For example, what is called a "tripod" is often called a "giraffe" by the French. The giraffe *does* have a long neck. As for the jaw-breaking German words half a sentence long, the specificity of these long drawn-out words made up of combinations of shorter words cannot be denied.

Linguistically speaking, we, in the English-speaking countries, have lately learned the trick of making up words out of what philologists sometimes called the "compressed wreckage of words and phrases." A famous example is the term UNESCO, a synthetic word deliberately composed of little pieces of six other words—United Nations Educational, Scientific and Cultural Organization (a group, by the way, with which the SMPTE Interim Committee on Nomenclature is about to cooperate on an international scale). We confidently expect that it will be a lot simpler to achieve unanimity in the field of motion picture and television terminology than it has been in the realm of international politics.

Most of you will recall a recent issue of the *Scientific American*[2] devoted to the subject of automatic control. Whenever automatic control is discussed—and it will be discussed more and more in the film industry—the terms information theory, feedback, servo-loops, messages, bits, noise, redundancy, ambiguity, etc., also come up.

There is one statement in particular which I would like to quote from that issue of the *Scientific American*: *"All transmission systems are based on the idea that both the sender and the receiver have previously agreed as to what shall constitute the permissible range of messages."*

This idea applies just as neatly to *human* systems of communication as it does to communication in automatic fire-control systems. Furthermore, this concept is fundamental in any nomenclature work, because a nomenclature system is nothing more than a system for the transmitting and receiving of information.

I should like to recall a message that is famous in the motion picture industry. In this case a perfect prior agreement existed between the sender and the receiver as to the permissible range of meanings of the message, despite the fact that no *conscious* attempt had ever been made by anybody to reach such agreement. Because of the unanimity the message came through with zero ambiguity and zero redundancy. The message—and I hope I am giving it correctly—was "Hix Nix Stix Pix."[3] Let students of information theory take note of how narrow a portion of the avail-

* Presented at the 73rd Semi-Annual Convention of the Society of Motion Picture and Television Engineers, Los Angeles, May 1, 1953, as part of the Progress Report of the Interim Committee on Nomenclature of the SMPTE.

[1] *A Word in Your Ear; a Study in Language.* Program No. 1 in the series, Ways of Mankind, station WNYC, script writer, Lister Sinclair, 1953.

[2] September, 1952.

[3] *Variety,* July 17, 1935.

able band width this message utilized and how effectively its utter simplicity overrode any possible system noise.

It is doubtful that the Interim Committee on Nomenclature can provide anything as terse as that, but we do hope, in time, with your help, to achieve agreement between senders and receivers—between writers and readers, and between speakers and auditors as to the permissible range of messages.

At this point, I should like to repeat a comment from the same radio program cited above: *"One man's language is another man's jargon."* In almost every case, you will find that the jargon feeling stems from a lack of specificity, or from multiple meanings, or from the fact that a given technology has grown faster than its nomenclature. Also foreign words, although they can generally be translated *literally* from one language into another, often are stripped of important connotations. What is even worse, they sometimes acquire *new* connotations that weren't intended in the first place. There have been many instances where this type of trouble—*connotation failure*, to coin a phrase—has caused far-reaching difficulties.

Take the Italian word *canali*.

The year 1877 was quite a year in astronomy. For one thing, an American named Asaph Hall discovered that the planet Mars had two small moons. And then came news from Italy, slightly garbled in transmission, that an astronomer named Giovanni Schiaparelli had discovered canals on Mars. This story, which is well known in the history of modern astronomy, is very nicely told by Willy Ley, in his book, *Rockets, Missiles and Space Travel*.[4]

But to go on: Did Schiaparelli himself actually announce that he had seen "canals" on Mars? By no means. Schiaparelli, who was a sober, conservative scientist, had merely stated that he had seen *canali* on Mars, using the Italian word. Now, the primary meaning of the Italian word *canali*, according to Mr. Ley, is grooves or channels. A secondary meaning is artificial waterways, or canals, that is, canals as *we* understand them—the canals of Venice, the Panama Canal, or the Gowanus Canal in dear old Brooklyn.

To quote Willy Ley: "In all other languages, the word 'canal' means only that [*i.e.*, an artificial waterway]. And Schiaparelli's 'canali' was quickly, wrongly and unsatisfactorily translated into 'canals'. The jubilation was great." And then Mr. Ley adds ironically: "The planet which had logically been pronounced the most likely abode of intelligent life in our solar system now showed by gigantic works of engineering that it was."

Did this seemingly unimportant connotation failure end right there? Unfortunately not; this connotation failure gave rise to thirty years of wild, uncritical, unscientific enthusiasm about alleged intelligent life on Mars. For thirty years, responsible scientists were sucked into the happy madness about Mars when they could have been training their telescopes, mathematics, and insight on more important celestial phenomena. And all because of an international *nomenclature* failure!

Could this happen today? I'm afraid it could. Norbert Wiener, of computer fame, made a recent statement in which he deplored the fact that the term "electronic brains" is so often applied to computers and computing mechanisms. You may want to dismiss this as just another case of inaccurate, unrigorous terminology. I wonder if we have a right to take so cheerful a view of the matter. From a scientific standpoint, it is presumptuous to call an electronic computer a brain. It is true that human brains are *not* capable of the high-speed repetitious mathematical operations of certain electronic computers. But where is the computer that is capable of the kind of intellectual synthesis, projection, and imagination which even the most ordinary human minds perform every day? Where is the computer into which you can feed a load of misinformation, inaccuracies, and "hunches" and which will nevertheless come up with the right answer? We should think of these impressive machines not as "electronic *brains*" but rather as "idiots savants"; this is a French term used by psychologists to denote human individuals of very low basic intelligence who are nevertheless able to perform fantastically accurate and rapid arithmetic calculations in their heads.

Getting away from the more philosophical aspects of automatic computing devices, look at the prosy, everyday aspects of computers and their little brothers, the servomechanisms. In our business we have already witnessed the introduction of the servomechanism for lens-focusing and iris adjustment in television cameras. People who attended the last two annual IRE shows in New York City have seen television studio cameras which can be operated entirely by remote control: It is possible to swing the turret, focus whatever lens happens to be in position, or alter the diaphragm setting. By remote control, the studio camera can also be panned right, panned left, or tilted up or down. There is no doubt that before long we will have similar servomechanisms on standard motion picture cameras. It is possible that, when that day arrives, there will be a preperforated timing strip, programming very completely all the lens-focus settings and all the diaphragm settings to be used in the filming of a television show. It is also possible that we shall have a similar programming strip which will feed information to a set of servos and that they, in turn, will handle all the lighting changes on such a show.

The step between the written cue and the punched-card cue, which is analogous to the preperforated timing strip, is not as big a step, technically, as it may seem at first glance.

[4] Viking Press, 1951.

After all, motion picture laboratories which print film have used preperforated timing strips for years. It is entirely likely that, before long, analog-computing devices, with servos and appropriate feedback loops, will control much of our film processing.

Automatic control is coming in color, too, in the new machines soon to be announced. One example is a color printer capable of providing the equivalent of 8000 different filter combinations—twenty lights on each one of the three color components, independently of each other. And not a single physical filter is required to provide these 8000 combinations.[5] The original idea was to do it electronically, but we now find that it can be done without any electronic tubes at all—with little memory devices called relays!

What it comes down to is that we are going to need nomenclature, clean, precise nomenclature, devoid of double meanings, nomenclature with a high degree of specificity. We are going to need pertinent nomenclature for motion picture computing devices, for servomechanisms to be used in the industry, for 3-dimensional and for wide-screen techniques. We are going to need definitions for such terms as stereopsis and for depth perception, which, incidentally, do not necessarily mean the same thing. What is more, we will have to know the specific meanings of physiological and ophthalmological terms such as fovea and accommodation, retinal image and flicker fusion frequency. With color television we may soon be using terms like excitation purity, brightness channel, breezeway, burst pedestal (color burst pedestal), color-carrier reference, color phase alternation, etc.

The SMPTE Interim Committee on Nomenclature will try to keep a careful record of the nomenclature activities of the IRE, the NTSC, the AES, and numerous other bodies both here and abroad with a view toward issuing lists of specialized terms as quickly as the need for them arises.

---

[5] Since this paper was delivered, the number of printer lights available on each one of the color components has been raised to 40. This yields 64,000 possible combinations using no more than three basic physical filters.

Multichannel Sound Reproduction*

WALTER T. SELSTED
Ampex Electric Corporation, Redwood City, California

AS YOU ALL know, there has been a revolution in the motion picture industry. A few years ago the industry would not consider the use of magnetic recording for release print. Yet today, it is clamoring for multiple-channel magnetic reproducing systems. It is the reproducing equipment of the type required for CinemaScope film which will be described here. Twentieth Century-Fox engineers have decided to equip the release print with four magnetic tracks. Three of the tracks are to supply input signal for three on-screen channels, and the fourth supplies sound effects through surround speakers. The physical arrangement of the tracks on the 35-mm film can be seen in Fig. 1. Note that the tracks are inside and outside the sprocket holes and are very close to them. Performance specifications for a good reproducing system were established as follows. Flutter should be less than 0.15%; the signal-to-noise ratio should be in excess of 45 db, relative to 3% harmonic distortion; the frequency response should be approximately 40 to 8000 cps ±1 db or so. To meet these requirements is not particularly difficult, and, as will be pointed out later, they may be greatly exceeded. In order to reproduce these sound tracks, the following equipment would be needed: (1) a low-flutter film transport; (2) magnetic reproduce heads with adequate shielding; (3) suitable preamplifiers for raising the level of the head output; (4) power amplifiers with suitable theater level gain control; (5) suitable speaker system; (6) power supplies and emergency projection equipment and switching.

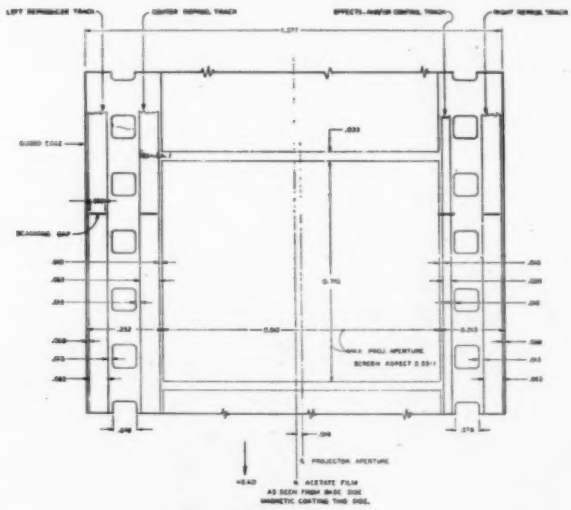


FIG. 1. Film standards.

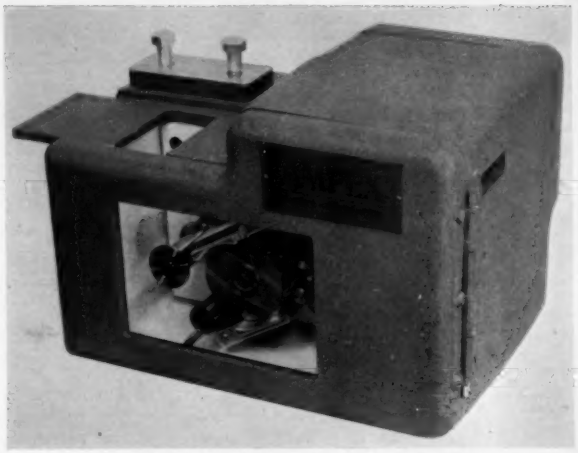


FIG. 2. Film transport (sandwich).

Ampex has undertaken to design and build these required components for such an installation. In describing the system in detail, one might properly start at the sandwich, head house, or button, as it is variously called. This unit is the sound track reproducer which is added to the projector and which takes the place of the sound head normally used to reproduce optical sound tracks. Figure 2 shows such a unit with its access door closed. This unit contains all the necessary components, mechanical filters, etc., required to transport the magnetic track past the magnetic head in a smooth, uniform motion. Figure 3 shows the same unit mounted on a typical projector with the door open. As you see, the unit has been inserted between the top of the projector and the bottom of the film supply magazine which was formerly mounted on the top of the projector. The path of the film with this arrangement is now from the magazine through the sandwich mechanical filter, past the heads, and then into the projector where the optical portion of the record will be reproduced.

Figure 4 presents a close-up view of the sandwich showing how the film path is arranged. Note that the film enters

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.

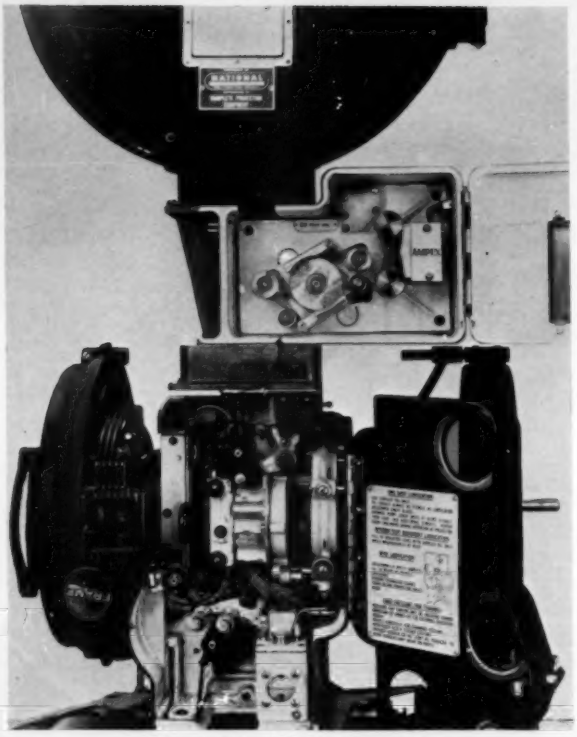


FIG. 3. Mounted film transport.

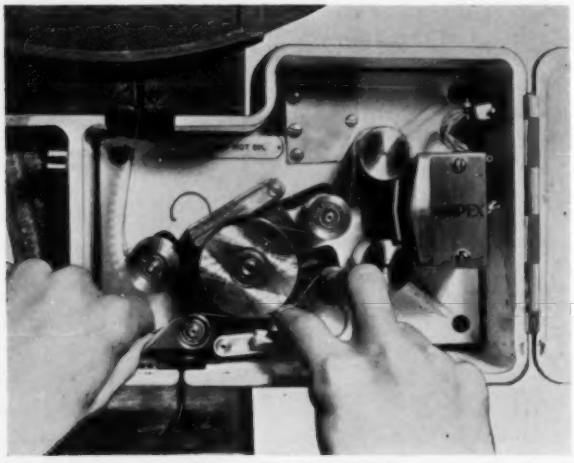


FIG. 4. Threading film.

the sandwich in the upper left-hand corner, passes over a roller which is spring-loaded to take up shock, thence over the large-diameter sprocketed pulley in the center of the sandwich. Proceeding to the right, it goes past suitable pulleys and two flywheel idlers, thence back over the other half of the sprocketed pulley, and out to the projector. The idlers between the sprocketed pulley and the two flywheel idlers are spring-loaded and suitably arranged with a dash pot so that the speed irregularities caused by variations in supply reel tension and projector sprocket motion will be effectively filtered out. Since the film motion is the most stable between the two flywheel idlers, it is here that the magnetic reproduce heads contact the magnetic track on the film. The reproduce heads are mounted within the magnetically shielded housing which bears the company name at the right-hand side of the sandwich. The head assembly is an entirely new design developed for this purpose. The foremost considerations in the design of this head assembly were long life, high uniformity of performance, and high quality of performance. With these objectives in mind it was still imperative that the cost of manufacture be held to the minimum, since cost of replacement of such a unit will be a very serious consideration on the part of the buyer. All these important objectives have been realized.

The characteristics of the sandwich are: flutter, less than 0.15%; frequency response, uniform from 50 to 15,000 cps; signal-to-noise ratio, approximately 55 db below 3% harmonic distortion record level on the film. The signal-to-noise ratio figure, of course, assumes no extremely high ac field in the immediate vicinity of the sandwich; however, even in the presence of the ac solenoid used to transfer from one projector to another, the signal-to-noise ratio specification of 45 db is usually met. It is customary in such cases to move the offending solenoid further away from the magnetic reproduce head. The output of the heads on the sandwich is carried by suitable multiple-conductor cable to the input of the preamplifier rack mounted in a plug-in arrangement, as shown in Fig. 5. One such preamplifier is provided for each of the four reproduce heads. It consists of a three-stage amplifier. The first stage is a high-mu triode with an equalizer in its plate circuit. The equalizer corrects for the

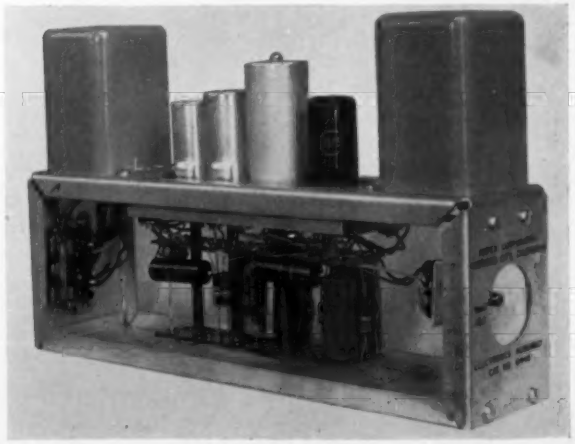


FIG. 5. Preamplifier.

FIG. 6. Remote transfer control.

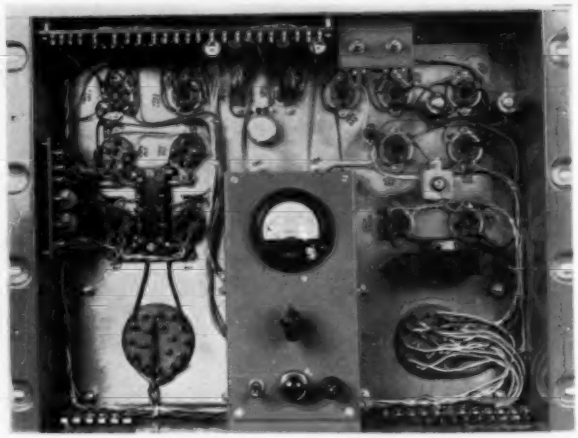


FIG. 7. Power amplifier (100 watts).

6 db per octave slope and provides post-equalization. The second and third stages are provided with sufficient gain and feedback to deliver the reproduced signal at a level of +4 dbm and a distortion of considerably less than 1%.

Since in the deluxe reproducing system one set of the four preamplifiers is provided for each sandwich, it is necessary to provide a transfer system whereby the output from either projector can be selected. The transfer from one projector to another is accomplished by means of a built-in fader arrangement within the preamplifier whereby one may be turned off and the other turned on simply by the removal or application of a high-biasing voltage on the output amplifier in the preamplifier. Transfer of the high-bias voltage is accomplished by means of relays operated from a remote transfer box of the type shown in Fig. 6. This remote control box will allow the projectionist to transfer the output to any of three projectors by merely pushing the button so labeled. The fourth button, to the right of the control box, transfers the power amplifier and speaker system back to the optical sound head so that no duplication of speakers or power amplifiers is needed for reproducing optical sound.

Following the preamplifier is a master gain control whereby the operator can set the house reproduce level. This gain control is a multiple gain attenuator with a ±20-db range. The output from the gain control is wired to the power amplifiers which are also rack mounted in a rack adjacent to that containing the preamplifiers. Those recommended for a 100-watt installation are the type shown in Fig. 7. This shows a bottom view of the 100-watt amplifier supplied in the deluxe system. The amplifier has a frequency response from 20 to 20,000 cps, a power output capability of 100 watts at 1% distortion, and an output of approximately 120 watts at 2% distortion. It utilizes four 807-type power amplifier tubes, very conservatively rated, in a class AB2 amplifier circuit. Sufficient feedback has been provided to keep the impedance reasonably low at the output of the amplifier and to reduce distortion to a satisfactory minimum. The noise level of the amplifier is approximately 85 db below 100 watts output. Four such amplifiers would be used in the 100-watt system recommended for theaters above 2000 feet. For smaller theaters there are power amplifiers rated at 30 and 60 watts and suitable speaker combinations to match these amplifiers. For the large theaters, however, a speaker system of the type shown in Fig. 8 is recommended. Three such speakers would be mounted on the stage behind the screen to reproduce the three on-screen sound channels. Such a speaker is equipped with four 15-in. low-frequency reproducers which are horn-loaded down to approximately 40 cps. Crossover is provided at approximately 500 cps, above which point the high-frequency units equipped with acoustical lenses take over.

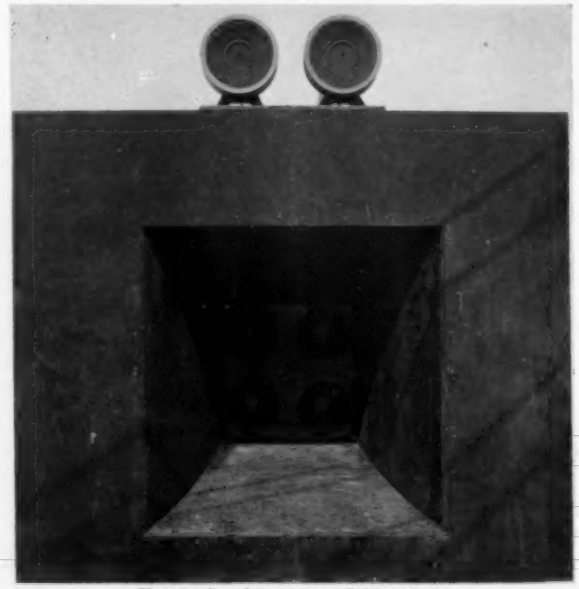


FIG. 8. Speaker system (120 watts).

The two high-frequency units are mounted in a diverging arrangement so that their energy distribution patterns cover an angle of approximately 110°. The frequency range of this system is extremely uniform from 40 to 10,000 cps. Useful response above 10,000 cps may be achieved by suitable equalization in the power amplifiers.

Since this equipment is to be used in motion picture theaters where an interruption in service would be extremely serious, it is necessary to consider every possible emergency. It is imperative that provisions be made so that any portion of the reproduce system can suffer a failure without losing any of the on-screen channels for more than a few moments. Assume for a moment that one of the four preamplifiers has a tube failure or a component failure within the plug-in strip. It is a relatively simple thing to withdraw the defective strip and replace it with the one normally used for sound effects in the surround speakers. If desired, a fifth preamplifier may be kept on hand as a spare. Assume for a moment a failure in the preamplifier power supply. The high-voltage dc supply is arranged in duplicate; therefore, in the event of a failure in the high-voltage supply the flip of a switch on the front panel of this unit will transfer the preamplifiers to the standby dc supply, thereby allowing continuance of the performance. The dc filament supplies for the preamplifiers are so arranged that in the event of failure the preamplifier filaments are transferred to the dc filament supply used for the transfer relay supply. Assume now that a failure develops in the dc supply for the relay. If this should occur, the relay functions can be carried out by means of toggle switches which parallel the relay contact.

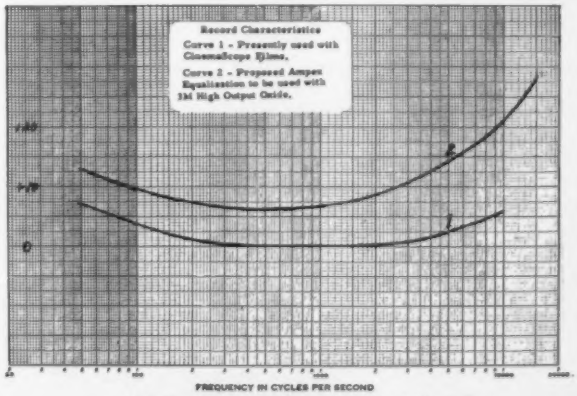
Another emergency feature which must be provided covers the possibility of power amplifier failure. In such an event, suitable toggle switches mounted on the emergency panel allow the defective amplifier to be removed from the circuit, and that amplifier normally used for the surround speakers is put in its place. Another arrangement makes it possible to mix inputs and outputs of two channels so that one amplifier carries the signal intended for two. This second provision takes care of the eventuality that a speaker system should fail completely or the leads to the speaker system might open up. In the 100-watt system the speakers themselves are so arranged that a failure in any of the components will go unnoticed by the audience since this system consists essentially of two 15-in. speakers and one high-frequency unit mounted in the same enclosure with their input connections paralleled. In smaller systems, however, the speakers are not arranged in this fashion and the emergency provisions mentioned previously are necessary.

It has been mentioned that the system described is considered to be a deluxe high-power reproducing system. Smaller, less expensive systems may be assembled from these basic components, however. These systems are provided with a total of four preamplifiers for two projectors, instead of four preamplifiers for each projector. The transfer of inputs from one projector to another is accomplished in the head leads by means of a suitable telephone-type switch. Since the transfer is made at this point, no relay transfer panel or remote control box is necessary, nor is one dc filament supply necessary for each bank of four preamplifiers. The emergency filament supply for the preamplifier is in the form of an ac filament transformer which reduces materially the cost of the preamplifiers and their power supplies. The power amplifiers may be 30-, 60-, or 100-watt units which, of course, must still have emergency protection switching already described.

The NARTB Standards Committee has established standard record and playback equalization characteristics for magnetic recording. These characteristics are being used in the CinemaScope process. The standards established by the NARTB were based on the use of full-track record heads on ¼-in. tape and a tape speed of 15 ips, and they were based primarily on theoretical compromise between sound energy distribution and magnetic oxide saturation characteristics.

Tests performed recently very definitely indicate that the record and playback characteristics which appear to have been best suited for ¼-in. magnetic tracks are no longer the most suitable for narrow tracks of the order of 50 thousandths of an inch. We have found that, with the standard equalization curve, high-frequency hiss becomes extremely objectionable to the average listener. Hence, a new compromise was sought between record pre-emphasis and playback equalization when very narrow magnetic tracks are used.

The results of these investigations show that a great deal can be done to improve the listening performance of narrow tracks. In Fig. 9, curve 1 shows the record current characteristic now being used as a standard recommended by the NARTB. Curve 2 shows the record current characteristic found to be far more satisfactory as a compromise between


Record Characteristics
Curve 1 - Presently used with CinemaScope Films.
Curve 2 - Proposed Ampex Equalization to be used with 3M High Output Oxide.
FREQUENCY IN CYCLES PER SECOND

F.G. 9. Record current characteristics.

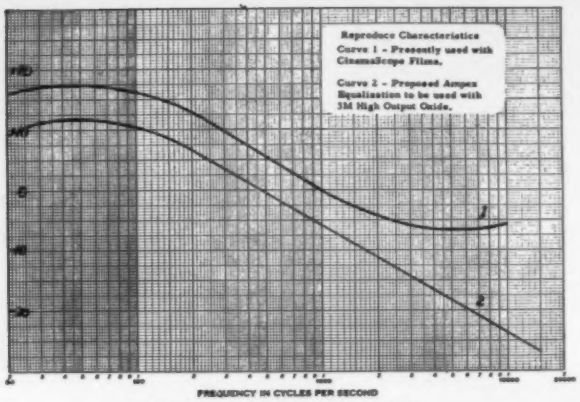

Reproduce Characteristics
Curve 1 - Presently used with Cinemascope Films.
Curve 2 - Proposed Ampex Equalization to be used with 3M High Output Oxide.
1
2
FREQUENCY IN CYCLES PER SECOND

FIG. 10. Playback characteristics.

high-frequency hiss level and high-frequency tape saturation. Figure 10 shows the complementary reproduce curve necessary for flat over-all reproduction when using the previous record curve. Note the spread between the two curves at the high-frequency end of the spectrum particularly. This spread in decibels is the improvement in signal-to-noise ratio at high frequencies. Note also the 6-db spread which exists throughout the low-frequency portion of the spectrum. This improvement is realizable only by using a different oxide in the magnetic track, such as the type recently announced by Minnesota Mining and Manufacturing Company. Recordings made using these equalization characteristics have been played in a three-channel stereo demonstration at the Audio Fair. This change in record and playback equalization has been recommended to the SMPTE Standards Committee for consideration. Should this standard be accepted, it will be entirely feasible and practical to extend the frequency response recorded on release prints to well beyond the 8000 cps to which it is now limited because of the relatively poor high-frequency signal-to-noise ratio. We feel confident that systems of sound reproduction of the type described will make theater attendance much more enjoyable. We feel certain that efforts on the part of the engineers associated with the motion picture industry and theater equipment manufacturers will advance the performance of stereo theater systems to the limit of the art.

A New Approach to Professional Magnetic Recording Equipment*

WILLIAM F. BOYLAN AND WILLIAM E. GOLDSTANDT
Magnecord, Inc., Chicago, Illinois

IT IS THE purpose of this paper to describe a new tape recorder, embodying a number of unique features which result in simple operation and easy maintenance, as well as superior performance and durability.

Before undertaking the design and production of a studio recorder, an extensive survey of the professional recording field was made in order to establish the most rigid specifications and criteria for a truly professional recorder. These specifications and performance requirements were closely adhered to in the design. Such basic features as accurate timing and low flutter, together with precise and rapid control of tape motion, were considered essential. Other features included in the design were ease of tape handling and operation, uniformity of recordings, low noise, extended frequency response, portability, appearance, accessibility of components for servicing, and simplicity of design.

FIG. 1. The console cabinet provided with the equipment houses both the recorder mechanism and the associated amplifier. A blower to provide forced ventilation for the equipment is included as an integral part of the console.

The recorder consists of two major units: the tape transport and the record and reproduce amplifiers. The console cabinet provided with the equipment houses both the recorder mechanism and the associated amplifier (Fig. 1). A blower to provide forced ventilation for the unit is included as an integral part of the console unit. The tape transport panel is mounted in a horizontal position, and the amplifier is mounted on an angle at approximately 30° off the vertical. This particular arrangement offers greater accessibility to the recorder for loading and editing and still allows easy access to amplifier controls. It also presents a direct view of all points on the tape path to an operator standing immediately in front of the unit. Storage space is provided at the bottom of the console cabinet. Access to this space is gained by opening the two doors in the front of the unit. The front panel immediately above the two doors to the storage space lifts up slightly to open a door safety switch and then slides beneath the mechanical unit, as shown in Fig. 2. This allows the tape transport mounting board to be swung forward in such a position that access can be gained to the working parts at the rear of the unit for servicing. The uppermost panel of the console unit swings up in such a manner that the amplifier mounting board can be swung completely around to permit access to the rear of the amplifier unit. Several holes are provided in the back of the cabinet so that input, output, and power leads may be brought in.

TAPE TRANSPORT UNIT

The complete tape-pulling mechanism together with the high-frequency bias and erase oscillator and control unit is constructed on a standard 19-in. rack mounting panel. The panel is 12½ in. high, and the mechanism extends 8 in. behind the panel. The unit is designed so that it may be used in a standard relay rack, mounted in a portable carrying case, or mounted in a console cabinet. The console cabinet and portable carrying case are provided by the manufacturer of the equipment.

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.

FIG. 2. The console cabinet, showing the accessibility of all working parts and assemblies.

One of the principal design objectives for this project was to produce a mechanism which would afford easy operation and tape handling. In order to accomplish this, considerable effort was directed to the problem of panel layout. Among the people interviewed, the general trend of opinion indicated that the normal tape direction should be from left to right in both relay rack and console-mounted machines. This arrangement dictated a front panel 19 in. wide with the height of the panel kept to the minimum to preserve portability.

In any professional recorder certain minimum components must be included in the panel layout: a constant-speed capstan and pressure roller assembly, a tape tensioning or holdback device, a takeup system to spool the tape after it passes the capstan, erase, record, and reproduce heads, compliance arms, and an inertia stabilizing roller. The arrangement of these components, shown in Fig. 3, not only governs the performance of the unit to a great extent but also affects the simplicity of operation. In the machine being described the tape path is straightforward and free of loops and curves.

A three-position function control lever has been included. The lever positions are marked, from left to right, "operate," "load," and "edit." When the lever is placed in the "load" position the compliance arms, tape guide, and head covers are placed in such a position that "straight-line" or "slot" loading of the tape is permitted. This feature eliminates most of the inconvenience frequently encountered in the tape threading of magnetic recorders. The head covers are open wide in the "load" position for ease of head inspection and marking of tape.

After the machine has been loaded with tape, the control lever is placed in the "operate" position. This brings the compliance arms and head cover back into their normal positions. In the "operate" position, the tape does not come into contact with the heads, except during normal forward operation. This allows the tape to be run at high-speed forward or rewind without excessive wear on the heads. When the tape is moving in the normal forward direction, as for playback or record, the tape guide and head cover are solenoid-actuated to cause the tape to engage the heads.

When the control knob is placed in the "edit" cue position, the pushbutton switches are locked out of the circuit, and the tape is held against the heads. If one reel hub is then gripped in each hand, the tape may be moved back and forth across the heads, thereby permitting easy and rapid cueing.

In addition to the function control lever, other controls located on the front panel include four pushbutton switches labeled, from left to right, "rewind," "stop," "forward," and "high forward." These pushbutton controls are located on the lower left-hand side of the front panel.

After the machine has been loaded with tape, no further manual tape handling is required to accomplish any of the functions governed by the pushbutton control.

Two rotary switches are located on the lower right-hand side of the panel, one of which controls the tape speed. The

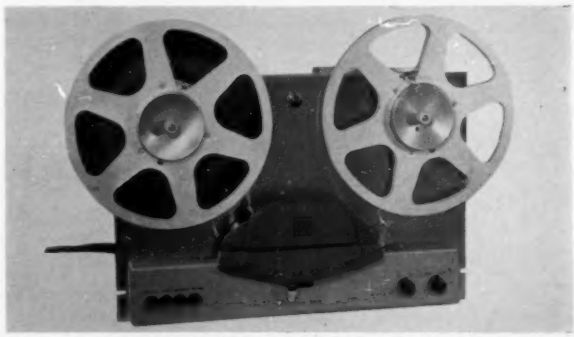


FIG. 3. Front view of the tape transport unit, showing the panel layout and tape path.

other rotary switch turns the recorder mechanism on and off.

A record indicator light is provided on the front panel which tells the operator when the unit is ready to record. This indicator light is lit when the record-playback switch, located on the front panel of the recorder amplifier, is in "record" position. When the tape is not in motion, the indicator light is excited by a dc voltage from the amplifier; when the tape is in motion, it is excited by the high-frequency bias supply which operates only when the tape is moving in the normal forward-record direction. This arrangement warns the operator that the unit is set for recording, and it minimizes the possibility of accidental erasure when a tape is to be reproduced.

DESIGN CONSIDERATIONS

The complete transport unit consists of eight unitized assemblies—two reel motor and brake assemblies, the capstan drive assembly, the stabilizer roller assembly, the head assembly, the front panel assembly, the pushbutton control box which houses the control relays, and the high-frequency bias erase oscillator. Figure 4 is a rear view of the mechanical unit showing the relative location of these assemblies.

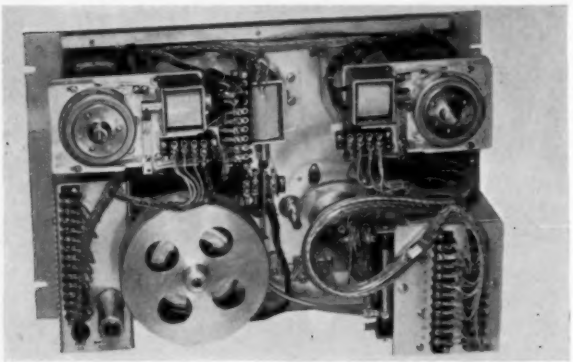


FIG. 4. Rear view of the tape transport unit, showing the placement of the unitized assemblies.

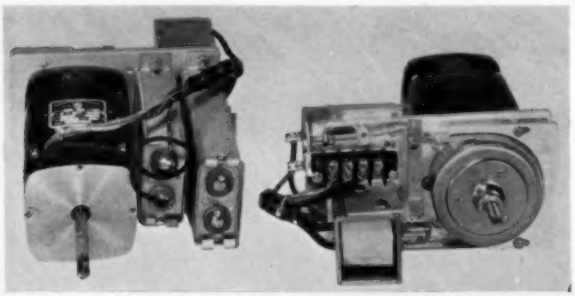


FIG. 5. Each of the two reel motors consists of a torque motor mounted directly on the front panel with a brake assembly mounted on the rear end of the motor.

FIG. 6. The capstan drive assembly consists of a 600/1200-rpm hysteresis synchronous motor with an integral ground capstan and a flywheel mounted on the rear shaft extension of the motor.

Reel Motor Assembly

Each of the two reel assemblies, shown in Fig. 5, consists of a torque motor mounted directly on the front panel, with a brake assembly mounted on the rear end bell of the torque motor. Braking is accomplished by solenoid-actuated band brakes, which provide for the necessary differential braking to keep the tape at a constant tension during braking. This eliminates the possibility of the tape's throwing loops when it is stopped after running in high-speed forward or rewind. The brakes are arranged so that when the solenoids are not actuated the band engages the brake drum, and when the tape is in motion the solenoids are actuated and release the brakes. With this arrangement, if the ac power should fail during operation, the brakes will be engaged and the tape will come to a smooth stop without tape breakage.

During normal forward operation, a reverse torque is applied to the payoff motor, which maintains a relatively constant tape tension while the tape is being unwound from the payoff reel. Slightly greater torque is applied to the takeup motor to provide sufficient torque to spool the tape after leaving the capstan. These two motors also provide sufficient torque for rewind and high-speed forward operation. The normal operating payoff and takeup torque are approximately 5 and 12 in.-oz, respectively.

The reel-mounting flange is mounted directly on the motor shaft, and adapter hubs are provided with the equipment to provide for operation with standard NAB reels. No adapter hubs are necessary when 7-in. plastic reels are used. A spring-loaded bayonet-type reel retainer knob is provided with which to attach the reels to the reel flange.

Capstan Drive Assembly

The capstan drive is accomplished by a direct drive assembly, shown in Fig. 6, consisting of a 600/1200-rpm hysteresis synchronous motor with an integral ground capstan, and a flywheel mounted on the rear shaft extension of the motor. The capstan drive motor is mounted securely on a panel mounting bronze casting which also contains an outboard bearing housing. The casting is then attached to the front panel securely with four large bolts. This unit is completely assembled and tested for total indicated capstan runout before it is mounted onto the machine. It will operate with the same characteristics in the horizontal as well as the vertical position. With this type of capstan drive, timing accuracy in the neighborhood of 3 seconds in 30 minutes can be expected.

Since a direct drive system requires a smaller capstan owing to the higher angular velocity, the runout tolerance of the capstan becomes very critical. It can be shown that flutter components caused by capstan eccentricity and runout are given by

$$F = K\left(\frac{dv/dt}{V}\right) = K\frac{dr}{r}$$

where F is the percentage of flutter.
K is a constant.
r is the radius of the capstan.
V is the tape velocity.

The equation shows that, as the capstan radius becomes smaller, the percentage of flutter increases for a given differential in capstan radius. This effect would indicate that capstan runout and eccentricity should be held to an absolute minimum if low flutter is to be realized. Manufacturing processes can be employed to hold the total indicated runout to a satisfactory degree. However, the capstan is subject to shock and the possibility of being bent when in use. In order to prevent such an occurrence, an outboard bearing has been added. This is a self-aligning Oilite bearing mounted in a housing which is an integral part of the one-piece motor mounting assembly. This arrangement assures accurate alignment of the bearing with the motor shaft.

Stabilizer Roller Assembly

The stabilizer assembly, shown in Fig. 7, consists of a flywheel, a tape roller and bearing housing, a compliance arm guide, and a tape break switch lever. This assembly filters out effects of tape sticking as well as high-frequency flutter components caused by the payoff reel. Precision ball bearings are used at the front and rear of the stabilizer roller shaft. A tape break switch, which is actuated when the tape tension is relaxed from the compliance arm, is mounted on the back side of the front panel. The complete assembly may be removed for service by removing the three mounting screws on the front panel.

Head Assembly

The high performance characteristics of the recorder are dependent to a large extent on the precision record and playback heads as well as the head mounting assemblies and tape guides. There are three heads in this assembly, as shown in Fig. 8, namely, the erase head, the record head, and the reproduce head.

The erase head is a low-impedance device requiring approximately 1 amp of ultrasonic current. The head is constructed of 0.01-in. laminations of Mumetal stacked together to result in an over-all thickness of 0.260 in. The erase head is of the double-gap variety, which assures complete erasure.

The record head employed is a new unit developed specifically for the recorder. The impedance of this head is ap-

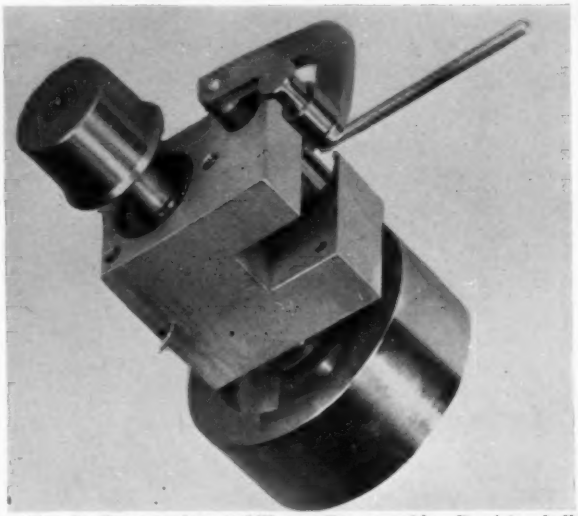


FIG. 7. The complete stabilizer roller assembly. Precision ball bearings are used in the front and rear of the stabilizer roller shaft.

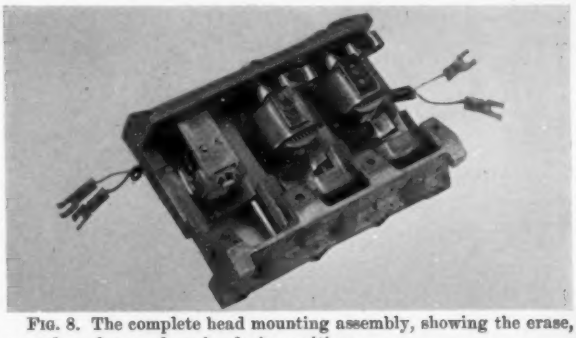


FIG. 8. The complete head mounting assembly, showing the erase, record, and reproduce heads in position.

proximately 50 ohms at 1000 cps. The record head is constructed of Mumetal laminations. Precision lapping such as that used in optical work has been employed to guarantee a very straight and uniform gap. Since recording is done with the trailing edge of the gap, the straightness of the gap edges becomes more important than the gap width itself. The record head gap width is of the order of 0.001 in. The reason for this large gap is to reduce the noise recorded on the tape owing to residual localized dc magnetizations of very small magnitude on the tape.

The reproducer head is similar to the record head in construction except that the gap width is of the order of 0.00025 in. The reproduce head is even more critical than the record head, and greater care must be taken in the manufacture of these units to assure uniform gap width as well as gap edges.

The impedance of the playback head is approximately 6500 ohms at 1000 cps. Various playback head impedances were tried during the development of the unit, and it was found that there are two determining factors which dictate the impedance of the head. As the impedance of the playback head is increased, greater output voltages are obtained, thereby lowering the requirements of the playback amplifier equivalent input noise. However, as the head impedance is increased, lower resonant frequencies of the playback head and connecting cable will be encountered. The resonant frequency of the playback and connecting cable should not be lower than the highest frequency to be reproduced.

The erase, record, and playback heads are mounted in triple-shielded Mumetal cans in order to reduce hum pickup from stray magnetic fields. Glass tape guides are employed to hold the tape against the heads during record and playback operation.

Front Panel Assembly

The front panel assembly, as shown in Fig. 9, contains mountings for the control box and oscillator units, plus the pressure roller assembly, a second compliance arm, tape guide linkages, and the power on-off switch and tape speed selector switch. The bottom panel cover, the head assembly covers, and the operational control linkages are also mounted directly on the front panel.

The pressure roller assembly consists of the pressure roller arm, on which is mounted the pressure roller bearing and pressure roller, together with the pressure roller linkage and solenoid. This linkage is adjusted so that when the solenoid is energized there is approximately 5 lb of pressure between the capstan and the pressure roller during normal record and playback operation. The tape guide linkage raises and positions the lower tape guide during recording and reproducing.

The on-off switch controls the ac power to the mechanical

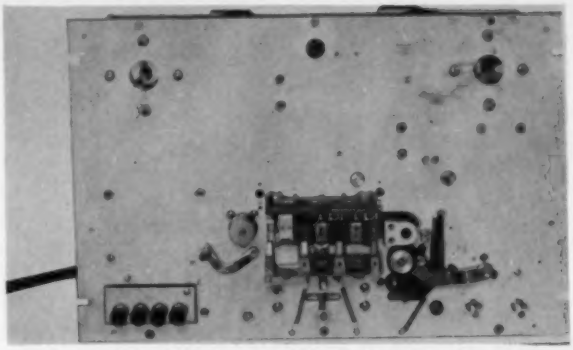


FIG. 9. The front panel assembly, showing the pressure roller and tape guide compliance arms.

unit. The two-speed selector switch controls the speed of the main drive motor and yields tape speeds of 7½ and 15 ips.

The button cover is painted hammerloid gray, the decorative head assembly covers a darker gray enamel. The stainless steel mat panel gives the unit a pleasing appearance. The head assembly covers are mounted with snap fasteners and may be easily removed to expose the head assembly by merely pulling them off from the front. With the head assembly covers removed, the heads may be cleaned and adjusted quite easily and are accessible for editing and marking the tape.

The bottom panel cover may also be released from its snap fasteners, thus exposing all linkages for more extensive servicing. This cover is removed by first taking off the on-off and speed selector switch knobs, together with the function control lever, and then simply pulling the cover from its snap mounting fasteners.

When the stainless steel mat panel is removed, all assembly mounting screws are exposed and any individual items may be easily removed.

Control Box Assembly

The control box assembly, shown in Fig. 10, is contained in a special mounting shell and is secured in the shell by the use of quarter-turn snap fasteners. All relays, pushbutton switches, and the relay power supply are mounted on a single chassis and are readily accessible for servicing during operation by simply removing the chassis from the mounting assembly. The relays are mounted in such a position that all contacts and residual adjustments are readily accessible.

There are four relays located on this chassis. Three of these relays have functions as follows: normal forward, rewind, and high forward. The relay coils are energized through the normally open momentary contact pushbutton-type switches and hold contacts on the relays. The normal forward relay supplies power to the payoff and takeup reel,

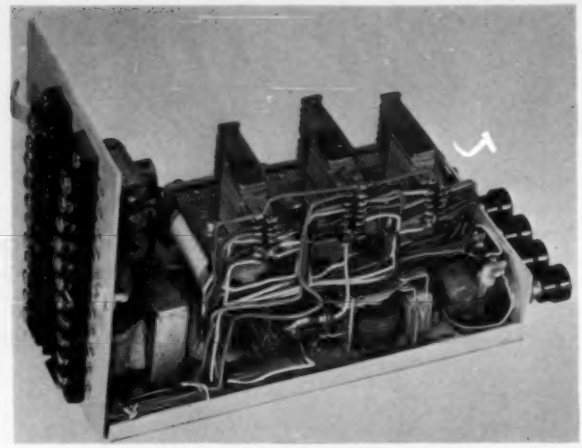


FIG. 10. The control relay chassis assembly.

as well as energizing the tape guide lifter solenoid, pressure roller solenoid, brake solenoid, and controls the $B+$ supplied to the bias oscillator. The rewind relay controls the power to the rewind motor and brake solenoids. These three relays have interlock circuits so as to prevent any two operations from occurring at the same time. In order to prevent tape breakage, the normal forward relay is locked out of the circuit until the machine is first stopped by pushing the stop button and de-energizing either the high forward or rewind relay.

An additional time delay relay—the time delay being accomplished by an RC network—is included to supply a voltage surge to the takeup motor when the machine is initially started in a normal forward mode. This feature prevents any looping of the tape between the capstan and pressure roller assembly and the takeup motor when the machine is started, thus resulting in a smoother starting.

All connections to the relay control box are brought out through Jones-type barrier strips. Six additional terminals are provided on this barrier strip to make remote control connections.

Oscillator Assembly

The oscillator assembly, shown in Fig. 11, is contained in a sheet metal housing which is hook mounted and held securely in place by two machine screws. It may be removed from the front panel by simply loosening two screws and lifting the unit from the hook fastening. The oscillator assembly is located at the lower left-hand corner of the front panel when the unit is viewed from the rear. This unit contains the high-frequency erase and bias oscillator circuits, as well as a 115-volt dc power supply used to energize the various solenoids. The high-frequency oscillator unit consists of a push-pull Hartley oscillator, using a type 12BH7 tube. This tube has a higher plate dissipation rating than a previously used type 12AU7 tube and should give longer service without replacement. A special improved high-Q oscillator coil has been employed, to result in lower even-order harmonic content.

The oscillator coil secondary feeds the erase head in series with a 0.1-mf coupling capacitor. This capacitor has the function of resonating the erase head inductance at the operating frequency of the oscillator, which is approximately 70 kc. Approximately 1 amp of high-frequency current is supplied to the erase head. The voltage drop caused by the reactance of the 0.1-mf condenser is used as the supply voltage for the high-frequency bias for the record head. Lower harmonic content is achieved by feeding the record head from a voltage source developed across a capacitive reactance, which results in lower noise being recorded on the tape.

The bias current is fed through a rheostat which is used for bias adjustment. This adjustment is made by means of a locknut type of potentiometer located on the back of the oscillator chassis assembly.

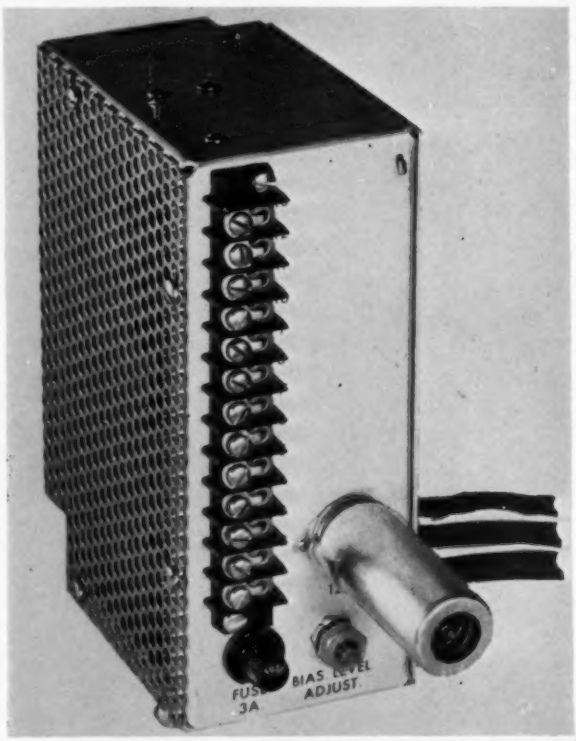


FIG. 11. The oscillator assembly is contained in a sheet metal housing which is hook mounted and held securely in place by two machine screws. It may be removed from the front panel by simply loosening two screws and lifting the unit from the hook fastening.

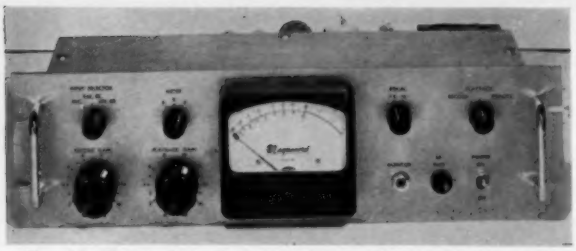


FIG. 12. Front view of the record reproduce amplifier, showing the placement of the various controls.

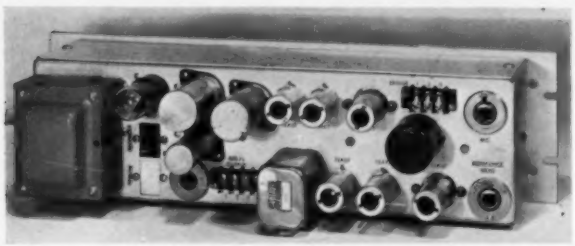


FIG. 13. Rear view of the amplifier, showing major component layout.

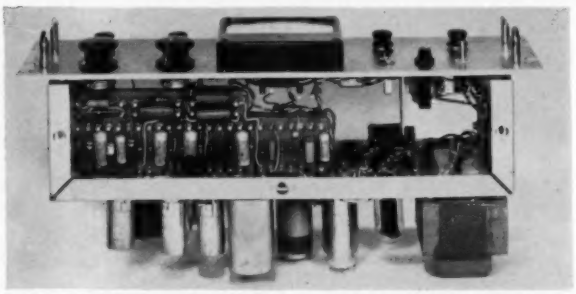


FIG. 14. The recorder reproducer amplifier with side panels removed. Resistors and capacitors are mounted on terminal boards.

RECORD AND REPRODUCE AMPLIFIERS

The record and reproducer amplifier is mounted on a standard 5¼-in. by 19-in. rack mounting panel, with a chassis mounting the tube and major components in a horizontal position. This arrangement is shown in Figs. 12, 13, and 14. The front panel of the amplifiers contains a record level gain control, a playback gain control, and an input selector switch for operation from a high-impedance balanced bridge input, a high-impedance unbalanced bridge, or a 50-ohm microphone input. A VU meter function switch is provided with three positions, namely, "record level," "playback level," and "bias." The "bias" position on this switch allows the operator to monitor the high-frequency bias supplied to the record head. Also included on the front panel is a record-playback switch with three positions: "record," "playback," and "remote." When this switch is in "remote" position, the amplifier record or playback function can be controlled from the remote location. A monitor jack is provided on the front panel to provide monitoring directly from the program source or monitoring from the tape. The monitoring voltage is switched simultaneously with the VU meter. An equalizer switch is provided to accomplish the equalization at tape speeds of 7½ or 15 ips. The off-on switch controlling the power to the amplifier and a fuze mounting are also included on the front panel. The side cover panels of the amplifier unit chassis are attached by means of quarter-turn fasteners, thus providing ease of maintenance and servicing.

CIRCUIT DESCRIPTION

The amplifier unit consists of two amplifier circuits with a common power supply (Fig. 15).

Record Amplifier

The record amplifier contains three stages of voltage amplifications, followed by an output stage which supplies current to the record head and accomplishes the pre-equalization.

The input stage is a form of a newly developed cascode circuit, described by Wallman.[1] The use of this input stage results in lower equivalent input noise than most microphone preamplifiers commercially available. The production units have shown an input noise figure in the order of –127 dbm. The newly developed type 6BK7 tube is used in this circuit. The high amplification factor, together with the low plate impedance of this tube, makes it well suited for cascode application. The input stage is capable of handling input levels as high as –20 dbm without exceeding 1% total harmonic distortion. The large input signal handling capabilities, together with the low noise figure, results in an ideal microphone amplifier input stage. Approximately 6 db of inverse voltage feedback is carried around the input stage in order to increase the level handling capabilities. A 100-kohm high-quality gain control follows the input stage and in turn is followed by two stages of voltage amplification. These voltage amplifiers provide the necessary level to drive the output stage which supplies current to the record head.

The output stage consists of a constant-current inverse feedback type of amplifier, wherein a large cathode resistor is used to accomplish the feedback. Equalization is accomplished in the cathode circuit by employing a small bypass condenser across the cathode resistor, thus resulting in a higher gain with a higher frequency. This method is used for 15-ips tape speed. At 7½ ips a greater slope of the equalizer curve is required, so that a series resonant circuit

[1] G. E. Valley, Jr., and H. Wallman, *Vacuum Tube Amplifiers*, McGraw-Hill Book Co., New York, 1948.

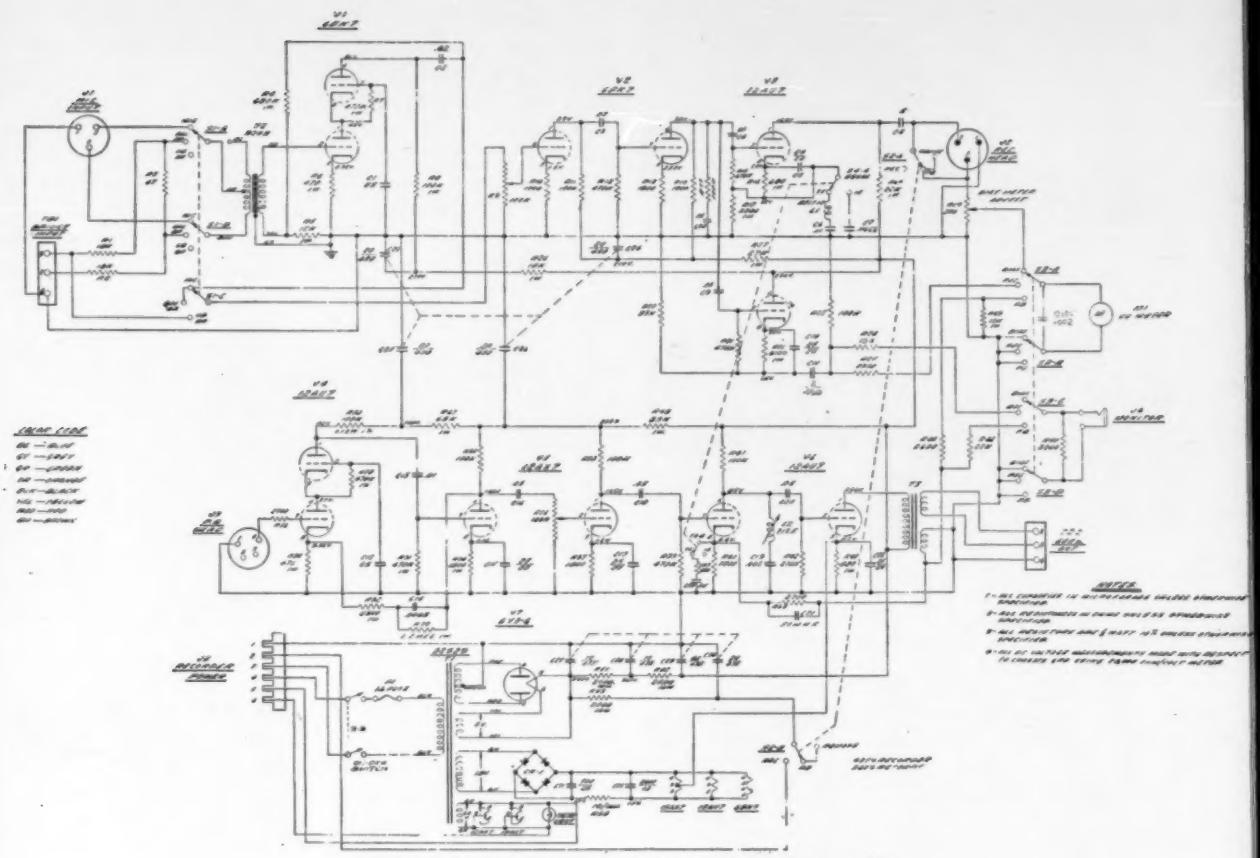


FIG. 15. Complete schematic of the record-reproduce amplifier.

is used to shunt the cathode resistor. Equalizations are of the order of 8 db at 15 kc for 15 ips and 16 db at 15 kc for 7½ ips.

The response of the recording amplifier is flat from approximately 30 cps to the point where the high-frequency pre-emphasis begins to occur. It is the opinion of the authors that low-frequency pre-emphasis should not be used in the record amplifier, in order to eliminate the possibility of overloading the tape at high-level low-frequency tones. Response curves are shown in Fig. 16.

The plate of the output stage connects directly through a 0.5-mf condenser to the record head. A potentiometer is provided in the ground return of the record head circuit. The bias current for the record head passes through this potentiometer, and a voltage proportional to the bias current is developed across it. A portion of this voltage is tapped off and fed to the VU meter, which gives an indication of the bias current during the recording process. The second of the two voltage amplifiers mentioned also feeds a cathode follower stage, which supplies record monitoring voltage to the VU meter and to the phone jack. The output impedance of the cathode follower is approximately 600 ohms. This impedance, together with the 3300-ohm VU meter series resistor, constitutes the proper impedance and time constant for proper damping of the VU meter. The over-all apparent gain of the record amplifier, at the microphone input, is 95 db. This means that an input level of –95 dbm is required for a zero level recording.

Reproduce Amplifier

The output voltage from the reproducer head is fed directly to the grid of a type 12AU7 input stage connected in a cascode arrangement. The connection from the playback head is made through a low-loss coaxial cable. The output of this stage feeds the first section of a 12AX7 dual triode cascade amplifier.

The output of the first section of the 12AX7 is fed back through an inverse feedback loop to the cathode of the input stage. This is a selective voltage feedback network which

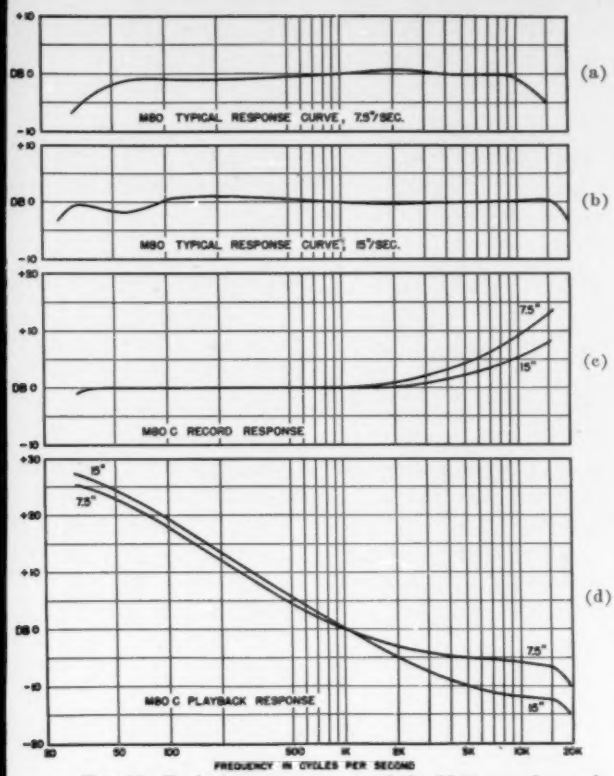


FIG. 16. Typical response curves of the M-80 recorder equipment. (a) and (b) Record playback frequency at 7½ ips and 15 ips. (c) Frequency *vs* amplitude characteristics of record current. (d) Frequency response of playback amplifier.

results in over-all frequency-gain characteristics very closely in agreement with the standard NARTB playback curve. This curve consists of approximately 27 db of additional gain at 50 cps above the 1000-cps gain; the gain at 15 kc is approximately 12 db below the 1-kc gain (Fig. 15).

Several types of tubes were tried in the input stage; these included the so-called low noise pentode and various dual triodes. However, it was found that the type 12AU7 connected in a cascode arrangement resulted in the lowest over-all noise figure.

The over-all gain of the playback amplifier is approximately 75 db at 1000 cps. There is an additional gain of approximately 27 db at 50 cps. Since most of the noise consists of low-frequency components, the gain affecting the noise output is of the order of 95 db. Calculations will show that the equivalent input noise, due to the input stage, is extremely low. This is a criterion which must be necessarily satisfied in order to achieve over-all high record-playback signal-to-noise ratios. It may be safely stated that with any high-quality recorder the determining noise should be confined strictly to the tape output noise, and the amplifier noise should be held at least 5 db below the tape noise. This requirement has been satisfied in the design.

The playback gain control is located between the second and third stages of the amplifier. It is followed by two stages of triode amplification, which in turn are followed by an output stage consisting of one-half of a 12AU7 dual triode. The output transformer has two 600-ohm secondary windings, one of which is carried directly to the output terminals, a barrier strip on the rear of the chassis. The other secondary winding is used for developing constant-voltage inverse feedback around the output and driver stages and also to supply voltage to the monitor jack and the VU meter. There is approximately 20 db of feedback around the output and driver stages, which results in distortions of less than 1% at the full rated output of plus 16 dbm.

When the equalizer switch is in the 7½-ips position an RC network is connected across the cathode of the driver stage in order to modify the playback curve for 7½-ips reproduction. The result of this network is to increase the high-frequency response by about 6 db, so that frequencies of 15 kc may be played back at tape speed of 7½ ips.

The power supply for the amplifiers consists of a transformer-fed single-phase full-wave rectifier, followed by an RC-type low-pass filter. Filament voltages for the input stages of each of the two amplifier sections are supplied from a rectified and filtered 18-volt winding of the power transformer in order to maintain low hum content, whereas filament voltages for the last two stages are supplied directly from a 6.3 winding. Alternating current for the amplifier is obtained from the tape transport unit through a power cable and Jones-type connector. The plate and filament voltages are supplied to the bias oscillator on the tape transport unit through this power cable.

PERFORMANCE

Over-all performance specifications of the recorder are as follows: Tape speed of 7½ and 15 ips with timing accuracy within 3 seconds in 30 minutes; starting time less than 0.1 second; stopping time less than 2 in. of tape when recording or playing back; flutter and wow at 15 ips under 0.1% rms, at 7½ ips less than 0.15% rms; signal-to-noise ratio in excess of 58 db, based upon 3% total harmonic distortion; frequency response ±2 db from 30 cps to 15 kc at 15 ips and ±4 db from 30 cps to 15 kc at 7½ ips; total harmonic distortion less than 1% for "zero VU" record and playback.

This recorder thus meets the most stringent performance requirements of the professional user and provides the utmost in simplicity of operation, ease of maintenance, and durability.

System Design for Multiple Copying of Tape and Disk Program Material*

ROBERT D. WINSTON†
Audio and Video Products Corporation, New York, New York

THE ART of magnetic tape recording has opened new vistas in the techniques and quality of the sound recording industry. By using the fine professional tape recording equipment available today, wide-frequency, low-distortion tape masters can be easily made. The resultant improvement in the quality of the sound of today's commercial recordings is quite evident. However, the industry has been cautiously watching for the possibility of the next major step in the art—prerecorded tape. The inherent advantages of tape over disk, including lack of surface scratch, full frequency response, and reusability of the tape itself, seems to indicate that this step is primarily a matter of time.

However, aside from the commercial aspects of public acceptance, improvement of moderate-priced home equipment, reduction in cost of raw tape stock, etc., another very real problem exists. This is the ability of the industry to turn out a duplicate copy of the original that preserves all the true fidelity of the original and still can be produced in quantity cheaply.

Various companies have been experimenting with the problem of mass duplication for many years. As far as can be found out, two techniques have evolved. One is a printing process wherein the original master tape and a virgin tape are maintained in close contact with each other and passed through a magnetic field at high speed. The resultant copy is not a true facsimile of the original, suffering primarily from distortion and a loss of high frequencies. The other method is to run a number of reels from a common capstan and allow each tape to pass over a separate record head. For various reasons, copies made in this manner are not entirely satisfactory with respect to the various quality requirements associated with tape recordings.

We are, therefore, faced with the problem of developing a satisfactory technique for the mass duplication of tape. If the broadcast industry is to use tape and if the record industry is to convince the general public of the advantages of tape, the tape copy must be an exact duplicate of the original master tape.

About two years ago, the A-V Tape Libraries, Inc., was formed for the purpose of making available a catalog of prerecorded music on tape. The big problem was to produce professional high-quality duplicates in quantity. The following technique was evolved by the engineering departments of Audio & Video Products Corporation and Ampex Electric Corporation. The system was made possible by utilizing a new recorder developed by Ampex for use in recording frequencies to 100,000 cps. This equipment is being used today primarily for data and telemetering recording requirements. By utilizing the wide-band frequency response and operating at a multiple of the original speed, the entire range of the audio spectrum can be reproduced without loss. Figure 1 is a block diagram showing the over-all setup of the system.

The Ampex tape transport mechanism that is used for playback of the original tape is a standard telemetering recorder except for the head assembly, which has been modified. There are no erase or record heads, but separate half-track playback heads are utilized. These heads are staggered vertically and will reproduce both tracks of a dual-track tape simultaneously. To complete this unit, two playback amplifiers are used, one for each head. The 600-ohm output of each playback amplifier terminates at line level in the audio equipment rack. Separate gain controls for each channel assure correct level between channels. The output of each gain control then terminates in channel busses 1 and 2. There are also a VU meter panel and a meter multiplier on the output of each playback amplifier gain control.

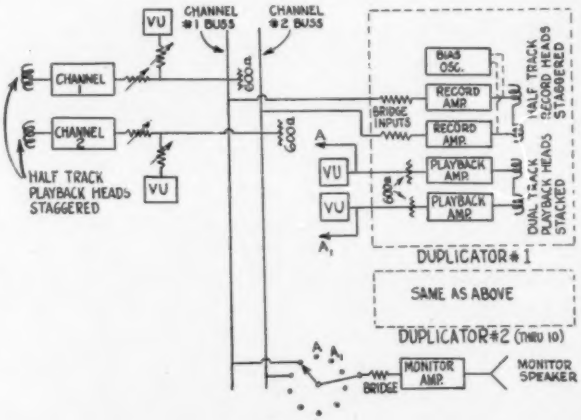


FIG. 1

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.

† Sales Manager.

The inputs to the duplicators are then multiple-bridged across the channel busses.

In the original installation there were five recording duplicators and the master playback unit. The duplicators are also modified telemetering transport mechanisms. The erase head has been eliminated, and all tapes are bulk-erased on a Cinema 9205 Tank Degausser. The bias current for the record heads is fed from a separate amplifier on each machine. The record heads are staggered in exactly the same manner as the playback heads in the master playback machine. In addition to the staggered record heads, stacked playback heads are used for monitoring the tape during recording. It was found imperative to stagger the record heads in order to eliminate crosstalk between tracks. When stacked record heads of 70 thousandths of an inch and employing separation of 90 thousandths of an inch were used, it was found that the best separation between tracks was of the order of 35 to 40 db. This is not sufficient separation when each track contains different material. The staggered record heads are each fed from a separate record amplifier on the electronics chassis. Similarly, separate playback amplifiers are utilized for the playback heads. With this dual-track setup, dual-track master tapes can be duplicated by simultaneously recording both tracks. A time and labor saving of 100% results from this technique alone.

Separate VU meter panels are mounted to the rear of each duplicator and are connected to the outputs of the playback amplifiers. This allows continuous visual checking of either or both channels during the duplicating process. For further monitoring and checking, an audio power amplifier is maintained in the audio equipment rack and a selector switch allows the operator to bridge the output of any playback amplifier across the input of the power amplifier. Inasmuch as the tape speeds are increased during the recording, the monitor loudspeaker offers indication of the existence or nonexistence of sound for a particular channel rather than an actual check of quality. In addition the tapes are run through backward, so that the finished tape can be removed from the takeup turntable of the duplicator and immediately placed in a box without rewinding. Quality control is maintained by actually playing every fifth duplicated tape.

Another novel feature that has been incorporated is the remote control panel. A bank of key switches actuates a group of relays by which the operator can start and stop all the equipment simultaneously or can remove any of the duplicators without changing the levels or motions of the others.

Recently another bank of recorders has been added to Audio-Video's facilities. The over-all installation is approximately the same as the one already described, with one major improvement. A master bias amplifier and master record amplifier are utilized. The two record amplifiers, one for each channel, are designed to pass the full range of frequencies up to 100,000 cps. This is done without discrimination and with negligible distortion. These amplifiers are of low effective source impedance so that they represent a constant voltage source for the record bus which each amplifier feeds. This is done to allow any number of record heads from one to a maximum of ten to be used with each amplifier. Heads may be removed or added, even during a recording, without affecting the performance of the other heads already paralleled across the bus.

General measurements of the system are as follows:

Frequency response:

3¾-in. duplicates, 50– 7500 cps
7½-in. duplicates, 50–15000 cps
Signal-to-noise ratio: 45–50 db
Wow and flutter: Measuring all components up to 300 cps, wow and flutter introduced by the duplicator will not exceed 0.2% rms.

In determining the actual quantities of tape that can be duplicated, the following ratios can be used. Assuming an original tape speed of 3¾ ips, and a duplicating speed of 30 ips, a ratio of 8:1 exists between the speed of the original tape and time required to make one copy. Since ten duplicators are involved, the ratio becomes 80:1. A 1200-second reel, therefore, which offers 1 hour of recording time (single track; 2 hours, dual track) can be duplicated in 7½ minutes of actual recording time. Inasmuch as ten reels are being made simultaneously, the effective time becomes 45 seconds per reel. Plans are in process to increase the 30-ips duplicating speed to 60 ips. This will necessitate increasing the frequency response to 120,000 cps. However, a 100% increase in quantity of tapes duplicated will be realized. A recent duplicating job indicates the amount of tape that can be duplicated with this equipment. Approximately 11,000 1200-second reels of tape were copied in one week. This amounts to a little over 13 million feet of tape, or approximately the distance from New York to California.

Some Notes on Problems Encountered in the Use of the Standard Reference Tape*

FRANK RADOCY†
Audio Devices, Inc., New York, New York

This paper discusses serious errors resulting from the use of a reference tape as the basis for a magnetic tape performance standard (Interim Federal Specification W-T-61a, Navy Ships). The accuracy of the method is seriously affected by physical changes in the reference tape, and the relative performance of two similar tapes depends significantly on the model of machine used for the test. Precautions for minimizing damage to reference tapes are described.

THE REFERENCE TAPE METHOD

FOR THOSE who are not acquainted with the reference tape method of standardization, the high points will be outlined briefly:

1. A reference recorder is selected which has certain minimum features, including specified limits on record and playback characteristics, flutter and wow limitations, and minimum bias frequency.

2. The next step involves the selection of a magnetic tape, which, when used in conjunction with the reference recorder, gives the desired performance. This tape is called the primary standard reference tape. The actual performance of this tape is secondary, since it is to be used only as a reference; therefore, the prime consideration in selecting the primary standard is its stability.

3. Standard reference tapes (which have been calibrated against the primary standard) can be used to adjust reference recorders for frequency response, operating bias current, maximum record level, and standard output level.

Standard reference tapes may be obtained from the Material Laboratory, Bureau of Ships, Department of the Navy, and are used in conjunction with Interim Federal Specification W-T-61a.

EFFECTS OF WEAR

The first problem concerns the changes in characteristics of a standard reference tape due to frequent use.

The particular standard reference tape concerned was used as a production standard against which daily samples of magnetic tape were checked. Within a week's time, it was obvious that a change was taking place. The high-frequency response of production samples appeared to be getting poorer, and a shift in peak bias seemed to be taking place.

A thorough investigation revealed that some of the characteristics of the standard reference tape had changed. Visual examination of the tape showed that the coated surface had become highly polished. Micrometer measurement of the tape revealed a 10% reduction in the coating thickness, as compared to the original measurement.

As a result of these physical changes, the performance characteristics were affected. Figure 1 is a graphic comparison of the bias, output, and distortion characteristics of the standard reference tape before any change occurred with characteristics of the same tape after much use. The data for these curves was taken on our No. 1 reference recorder at a speed of 7½ ips, a frequency of 1 kc, and a standard output level determined by the new tape. The output figures are arbitrary.

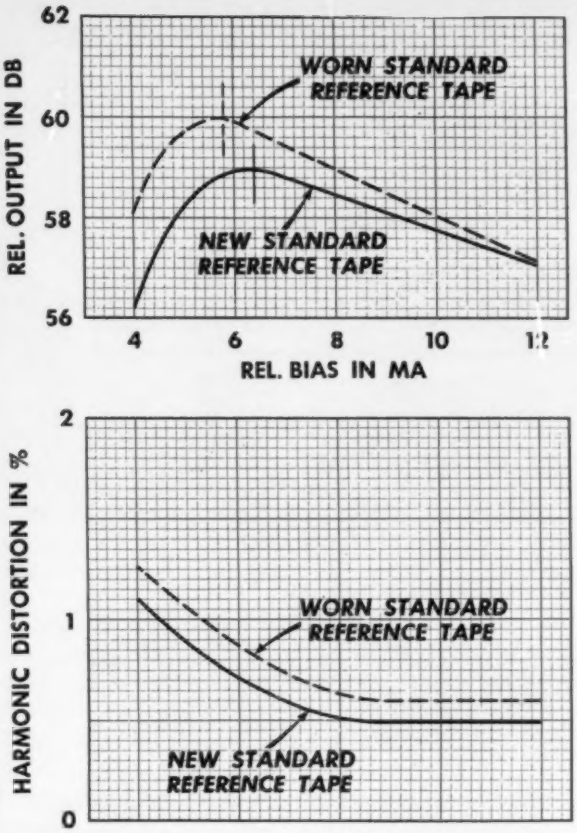
The uppermost section of Fig. 1 compares the bias *vs* output curves of both tapes. Notice that the curve of the worn tape has become sharper with an increase of approximately 1 db in maximum output and a 9% reduction in peak bias. Also note the slight increase in the distortion of the worn tape in the lower section of Fig. 1. The increase in distortion is not a serious change; however, it confirms the fact that a reduction of coating thickness has occurred.

Figure 2 is a set of frequency response curves, also taken on our No. 1 reference recorder at a speed of 7½ ips. The standard output level was determined for each tape so that a true comparison is shown. The procedure for determining the standard output level also involves the simultaneous determination of operating bias current so that the peak bias shift demonstrated by Fig. 1 has been accounted for.

The worn tape shows an increase in output of 3 db at 7.5 kc; at 5 kc the increase is 2 db; and at 1 kc the increase is 1 db. This is a considerable increase in response and can cause much confusion unless the user is aware of the changes taking place. Whether this particular tape is the exception has not been determined; however, it serves its purpose in revealing the changes that will occur with all tapes to some degree.

The best precaution to be taken, to avoid being misled by the changes described, is to obtain two standard reference tapes or to divide one tape into two sections, using one as a daily reference control and cross-checking weekly or monthly against the other.

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.
† Director of Quality Control.



Worn Standard Reference Tape			*New Standard Reference Tape*		
Bias	Output	Dist.	Bias	Output	Dist.
4 ma	58.0 db	1.20%	4 ma	56.2 db	1.10%
5	59.7	1.05	5	58.2	0.90
6	59.9	0.85	6	58.9	0.70
7	59.5	0.75	7	58.8	0.60
8	59.0	0.65	8	58.5	0.50
9	58.5	0.60	9	58.1	0.50
10	58.1	0.60	10	57.8	0.50
11	57.6	0.60	11	57.4	0.50
12	57.1	0.60	12	57.0	0.50
Peak bias			Peak bias		
5.8 ma	60.0 db	0.90%	6.4 ma	59.0 db	0.65%

(Output figures are arbitrary.)

FIG. 1. No. 1 reference recorder: frequency, 1 kc; speed, 7½ ips; standard output level determined by new standard reference tape.

PRECAUTIONS

Some other measures to minimize the wear and tear on a magnetic tape should also be practiced:

1. The "hold-back" and "take-up" tensions should be kept at a minimum, especially in hot, humid weather.

2. Small reels should not be used on machines designed only for large reels.

3. The largest hub diameter practicable for the operation should be used.

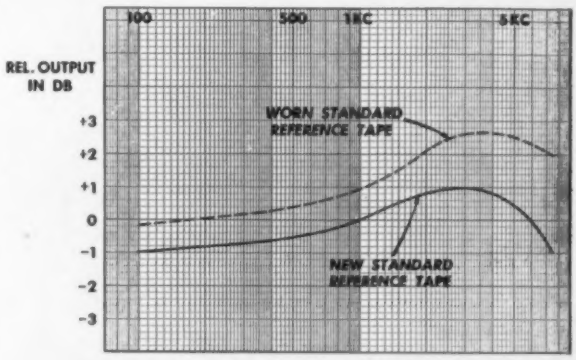
4. Machines with excessively hot erase heads should be avoided.

5. Tapes should be kept at constant temperature and humidity to avoid compression and distortion during storage.

EFFECT OF RECORDER CHARACTERISTICS

The second point to be discussed concerns the performance of the reference recorders. It is not expected that all recorders will have identical performance characteristics, but it has been generally assumed that the relative differences in the performance characteristics of two tapes would not be disturbed by a change of recording machines, so long as the machines conformed to the reference recorder specification. Unfortunately, this assumption now seems incorrect.

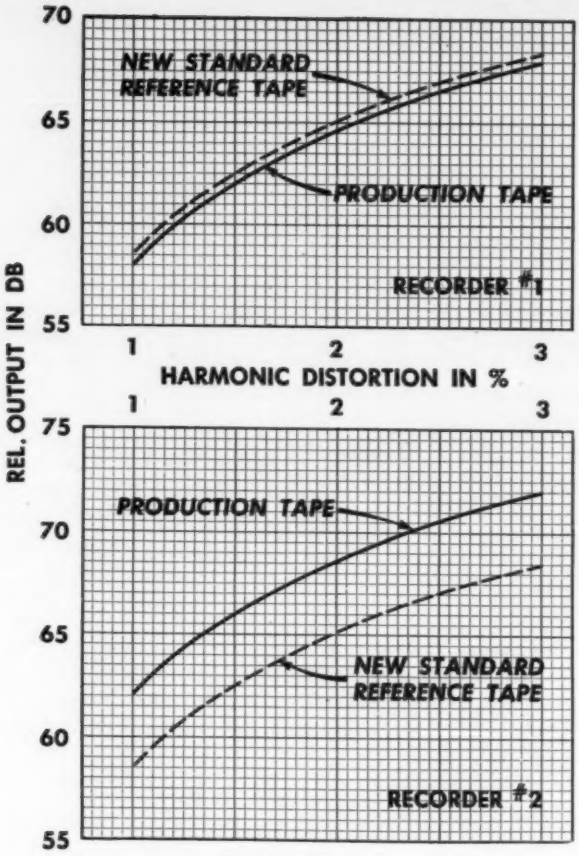
Figure 3 is an illustration of the output *vs* distortion characteristics of two tapes run on each of two separate recorders. In each case, the operating bias current was set at peak bias. The upper section of Fig. 3 shows the curves taken on our No. 1 reference recorder. A standard reference tape and a production tape appear to be within 0.5 db of each other. However, the curves of the same tapes taken from our No. 2 reference recorder, drawn in the lower section of Fig. 3,



Frequency	*New Standard Reference Tape*	*Worn Standard Reference Tape*
100	—1.0 db	—0.2 db
500	—0.6	+0.4
1 kc	0.0	+0.9
2 kc	+0.8	+2.1
3 kc	+1.0	+2.6
4 kc	+0.8	+2.7
5 kc	+0.5	+2.6
6 kc	0.0	+2.4
7 kc	—0.5	+2.1
7.5 kc	—1.0	+2.0

(Output figures are arbitrary.)

FIG. 2. No. 1 reference recorder: speed, 7½ ips; standard output level determined by each standard reference tape.



Recorder No. 1

Dist.	Production Tape	New Standard Reference Tape
1.0%	58.0 db	58.5 db
1.5	62.0	62.5
2.0	64.5	65.0
2.5	66.5	67.0
3.0	68.0	68.5

Recorder No. 2

Dist.	Production Tape	New Standard Reference Tape
1.0%	62.0 db	58.5 db
1.5	66.0	62.5
2.0	68.5	65.0
2.5	70.5	67.0
3.0	72.0	68.5

(Output figures are arbitrary.)

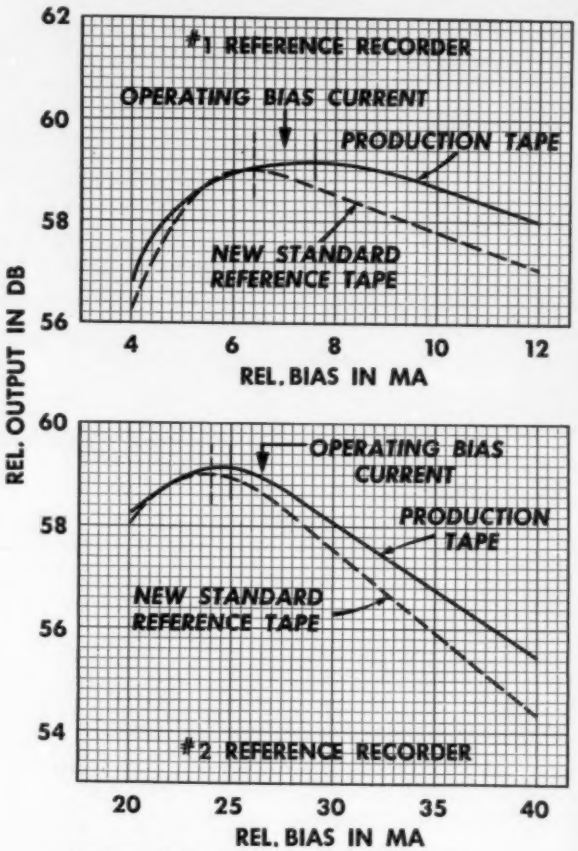
Fig. 3. Frequency, 1 kc; speed, 7½ ips; peak bias on each tape.

show the production tape to have 3.5 db higher output at 3% distortion than the standard reference tape.

BIAS EFFECTS

Figure 4 is an illustration of the bias *vs* output characteristics of the same tapes used for Fig. 3, on the same recorders. Again these figures were taken at a speed of 7½ ips, 1 kc, and at the standard output level determined by the new standard reference tape.

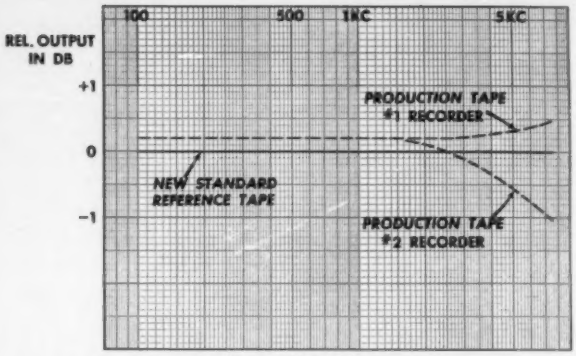
In accordance with the specification W-T-61a, the operating bias current is 110% of the peak bias current of the



Recorder No. 1				Recorder No. 2			
New Standard Reference Tape		*Production Tape*		*New Standard Reference Tape*		*Production Tape*	
Bias	Output	Bias	Output	Bias	Output	Bias	Output
4 ma	56.2 db	4 ma	56.8 db	20 ma	58.0 db	20 ma	58.2 db
5	58.2	5	58.4	25	58.9	25	59.1
6	58.9	6	59.0	30	57.5	30	58.1
7	58.8	7	59.2	35	56.0	35	56.8
8	58.5	8	59.1	40	54.4	40	55.4
9	58.1	9	59.0				
10	57.8	10	58.7				
11	57.4	11	58.4				
12	57.0	12	58.0				
Peak bias				Peak bias			
6.4 ma	59.0 db	7.6 ma	59.2 db	24 ma	59.0 db	25 ma	59.1 db

(Output figures are arbitrary.)

Fig. 4. Frequency, 1 kc; speed, 7½ ips; standard output level determined by new standard reference tape.



RECORDER No. 1

	New Standard Reference Tape		*Production Tape*	
Freq.	Actual Output	Converted Output	Actual Output	Converted Output
100	—1.0 db	0 db	—0.8 db	+0.2 db
500	—0.6	0	—0.4	+0.2
1 kc	0.0	0	+0.2	+0.2
2 kc	+0.8	0	+1.0	+0.2
3 kc	+1.0	0	+1.2	+0.2
4 kc	+0.8	0	+1.1	+0.3
5 kc	+0.5	0	+0.8	+0.3
6 kc	0.0	0	+0.4	+0.4
7 kc	—0.5	0	—0.1	+0.4
7.5 kc	—1.0	0	—0.5	+0.5

RECORDER No. 2

	New Standard Reference Tape		*Production Tape*	
Freq.	Actual Output	Converted Output	Actual Output	Converted Output
100	—1.5 db	0 db	—1.3 db	+0.2 db
500	—0.5	0	—0.3	+0.2
1 kc	0.0	0	+0.2	+0.2
2 kc	+1.0	0	+1.1	+0.1
3 kc	+1.0	0	+0.9	—0.1
4 kc	+1.0	0	+0.7	—0.3
5 kc	+0.5	0	0.0	—0.5
6 kc	0.0	0	—0.7	—0.7
7 kc	—1.0	0	—1.9	—0.9
7.5 kc	—2.0	0	—3.0	—1.0

FIG. 5. Speed, 7½ ips; standard output level determined by new standard reference tape.

new standard reference tape. Applying this adjustment of bias current to the No. 1 reference recorder (upper section of Fig. 4), we find our operating bias current to be 7 ma. This is about 8% less current than is needed to reach the peak bias of the production tape. In the lower section of Fig. 4, however, the same adjustment results in an operating bias current of 26.5 ma, which is 6% beyond the peak bias of the production tape. Obviously, the operating bias currents on these two recorders bear a different relationship to the peak of the production tape.

Figure 5 demonstrates the differences in relative frequency response on both recorders. The operating conditions remain the same as in Fig. 4. The output of the new standard reference tape is converted to show a flat response to 7.5 kc. The output from the production tape is drawn in relation to the converted output of the new standard reference tape. At 7.5 kc on the No. 1 recorder, the production tape produces 0.5 db more output than the standard. On the No. 2 recorder, the 7.5 kc output is 1 db lower. This relative difference of 1.5 db in 7.5 kc output on the production tape can be attributed to the bias irregularities described by Fig. 4.

It is easy to foresee the difficulties involved in trying to correlate performance characteristics through the use of a standard reference tape if the parties concerned have recorders that vary in characteristics as much as those in Fig. 3.

CONCLUSIONS

It would appear that the use of a standard reference tape does not, in itself, provide a reliable standard of tape performance, probably because of unforeseen reactions between tape and recorder characteristics. It seems necessary to provide a better definition of the test recorder than is presently available. It also seems desirable to pre-age standard tapes so that wear effects are overcome.

The Compound Diffraction Projector*

LOUIS S. HOODWIN
Electro-Voice, Inc., Buchanan, Michigan

A NEW HORN-TYPE loudspeaker has been developed to provide improved reproduction in public address and multiple-channel loudspeaker installations. The name of this unit is the compound diffraction projector (CDP). In order to determine how well it fulfills its design objectives, it is necessary first to determine the qualities desired in public address loudspeakers and the extent to which previous units possessed these qualities.

Although the qualities desirable in a public address loudspeaker will depend on the specific application of the loudspeaker, general requirements may be obtained by considering average applications and the demands those applications make on the five measurements of loudspeaker performance: efficiency, frequency response, polar distribution, distortion, and power handling capacity. To obtain a true picture of a loudspeaker's performance, all these measurements must be considered concurrently.

EFFICIENCY

Although a comparatively inefficient cone-type loudspeaker driven by 4 or 5 watts of audio power will produce more sound level than is usually desired in the average living room, most public address installations require relatively high sound levels and subsequently more efficient loudspeakers. Because of its relatively high efficiency, the horn-type loudspeaker is very widely used in the public address field.

Since it is generally not the purpose of a loudspeaker to produce just noise, in measuring efficiency more than just loudness must be considered. The true measure of the efficiency of a loudspeaker is the degree to which it reproduces intelligible speech and/or pleasing musical sounds at the position of the listener with a certain amount of audio power available. Therefore, if two loudspeakers are receiving the same speech signal and one is 3 db louder than the other but provides only 70% intelligibility, whereas the other provides 85% intelligibility, the loudspeaker with the lower acoustic output is for all practical purposes the most efficient. Sound level measurements for efficiency usually are made on the axis of the loudspeaker, using a single frequency or a restricted frequency range. Such measurements alone do not indicate the ability of the loudspeaker to produce sounds at the position of the listener, if the listener is off the axis of the loudspeaker. Neither do such measurements indicate the frequency and polar responses of the loudspeaker or the amount of distortion, factors which must be considered in determining the usefulness of the signal. Efficiency is determined not by axial loudness alone but also by frequency response, polar distribution, and distortion.

FREQUENCY RESPONSE

According to French and Steinberg,[1] a frequency range from 200 to 7000 cps is required for maximum speech intelligibility. The same authors show that the intelligibility index is lowered 20% by limiting the high-frequency response to 3500 cps. Good music reproduction requires a greater frequency range, particularly in the bass end. In some instances it is necessary to reduce the bass response of a system to prevent feedback or masking in very reverberant locations. But in order for a loudspeaker to be useful in the greatest number of applications, it should provide as wide a frequency range as possible within the limits of audibility. If there is need for limited or augmented frequency response at either end of the spectrum, it should be provided by the amplifier tone controls where such control is relatively easy to obtain. The best that should be expected of a loudspeaker is that it should have a frequency response that will require a minimum of equalization yet have sufficient frequency response to be equalized. In order to understand what is implied by "sufficient frequency response to be equalized," consider a case where an attempt is made to obtain maximum intelligibility by maintaining flat response out to 7000 cps, using a loudspeaker with a response that is 40 db down at 7000 cps and an amplifier that can provide 20 db of treble boost. In this case, equalization will be useless and the desired result will not be obtained. On the other hand, if the loudspeaker is down less than the available equalization, equalization may be used to good advantage.

POLAR DISTRIBUTION

In some cases it is necessary to project sound over a very great distance where the arc subtended by even a small angle will be large enough to cover the audience. Under such conditions, wide polar response is neither necessary nor desirable. But in the great majority of installations, the loud-

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.

[1] N. R. French and J. C. Steinberg, *J. Acoust. Soc. Amer.*, **19**, 90 (1947).

speaker is relatively close to the audience and the outside limits of the audience make quite a large angle with the loudspeaker. This is especially true in industrial paging and music systems. A polar distribution of 120° is generally adequate in such cases.

The usual axial frequency-response measurements are virtually useless for predicting the performance of a loudspeaker without knowledge of polar response, unless the listener expects to be situated only on the axis in an anechoic chamber or in free space—two conditions which are seldom encountered. Polar measurements are essential in determining what frequency response each listener will hear in various parts of the audience. These measurements must also be considered in determining the total energy output and efficiency of the loudspeaker.

POWER HANDLING CAPACITY

There are two methods of determining power handling capacity. One is based on a maximum permissible distortion; the other is based on the physical strength of the unit. Both methods should be used concurrently, since units with high distortion and good physical strength and those with low distortion and poor physical strength are both very limited in power handling capacity. It is also imperative to consider efficiency at the same time as power handling capacity. To illustrate by an extreme case, if a "permanent magnet" loudspeaker were made with no magnet at all, there would be virtually no diaphragm movement and the diaphragm would last indefinitely. Without diaphragm movement there would be no distortion. The coil assembly could be made to dissipate a large quantity of heat by winding the coil with nichrome wire on an oversized metallic coil form. Such a loudspeaker would have a tremendous power handling capacity when determined by distortion and physical strength requirements alone.

A NEW PUBLIC ADDRESS HORN LOUDSPEAKER

In order to fulfill the above-mentioned requirements in frequency response and polar distribution with good efficiency and power handling capacity and low distortion, a new loudspeaker called the compound diffraction projector (CDP) has been designed. But, in order to comprehend the degree to which the CDP is an improvement in the loudspeaker art, it would be best first to consider the advantages and disadvantages of the horn loudspeakers which were available before its advent.

STRAIGHT TRUMPET

The straight trumpet is the simplest type of horn loudspeaker. Its low-frequency response is determined by its rate of flare and mouth area. Low-frequency response requires a very gradual flare, and the mouth diameter of a circular horn must be one-fourth to one-third the wavelength of the lowest frequency to be reproduced to prevent reflections. For good bass response with small diaphragm driver units, these horns become quite long and unwieldy. A typical horn having a 115-cps cutoff is about 6 ft long without the driver unit, and has a 30-in. diameter mouth. The high-frequency output of the trumpet is usually limited only by the response of the driver unit. But, in cases where the walls of the horn have an appreciable absorption coefficient, a long horn may produce drastic attenuation of the higher frequencies.

The polar response of a straight trumpet narrows as the frequency increases, owing to the effective increasing ratio of radiator size to wavelength. Large trumpets produce narrower polar patterns than small trumpets. Therefore, if an installation requires a wide distribution of sound with level requirements which should necessitate the use of only one loudspeaker, a person making the installation using only straight trumpets must use either a very small trumpet with a resultant loss of the bass response essential for good quality, or a multitude of large horns which involves a considerable expense. Most attempts to obtain wide coverage with a few large trumpets result in either uncomfortable loudness for those who are near the axes of the units or unsatisfactorily low level for those who are situated off the axes. (The polar curves of a re-entrant horn, Fig. 1, are typical of the polar curves obtained from a straight trumpet of similar size.)

One of the most important sources of distortion in a horn

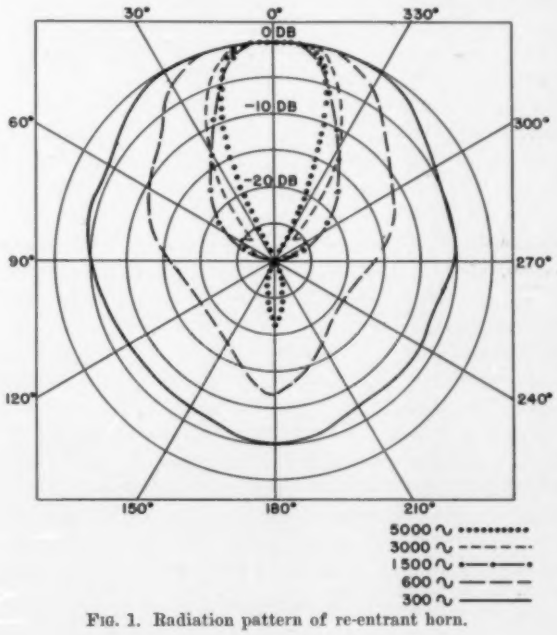


Fig. 1. Radiation pattern of re-entrant horn.

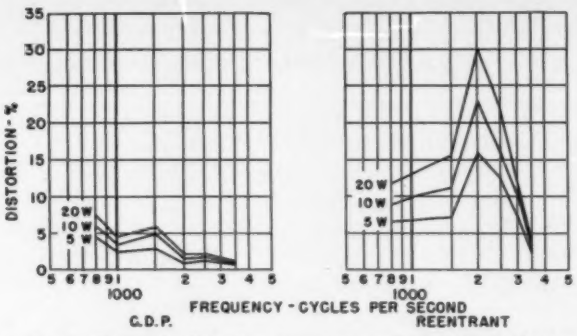


FIG. 2. Harmonic distortion curves of re-entrant horn and compound diffraction projector.

loudspeaker intended for high-level reproduction is due to the great compression and rarefaction of the air at the throat of the horn and the nonlinearity of the air, resulting in the creation of even-order harmonics. This distortion increases with both the sound intensity and the ratio of the frequency reproduced to the cutoff frequency.[2] From the foregoing it may be seen that large horns with low rates of flare exhibit more of such distortion than small horns. This is one of the reasons in favor of the use of multiple-channel loudspeaker systems. (The distortion curves of the re-entrant horn shown in Fig. 2 are also typical of the distortion produced by a straight trumpet of similar bass cutoff.)

MULTICELLULAR HORNS

The multicellular horn was developed to provide a better polar pattern than that available from the straight trumpet. These units actually consist of a cluster of straight trumpets coupled to one or more driver units through a common throat. The polar responses are limited only by the configurations of cells. But when many cells are joined, a constriction is often formed by the throats of the cells which has the effect of producing an acoustic cavity between the driver unit(s) and the cells. Such a cavity acts as a shunting capacitor which reduces high-frequency transmission, usually above 7000 cps.

The greatest disadvantages of the multicellular horn are cost, weight, and bulk. A typical horn having a 250-cps cutoff and a 3 by 6 array of cells is 28 in. high, 43 in. wide, 34 in. deep, and weighs 100 lb without driver units. A horn of this size and weight is virtually useless as portable equipment; and, since it has the relatively high cutoff of 250 cps, it provides very poor music reproduction. Because of the complexity of its construction, this unit costs around $150.00. These horns are used with separate low-frequency reproducers for high-quality installation; but where only speech reproduction is desired or where the acoustics of the location prevent the use of bass frequencies, they are often used by themselves.

RE-ENTRANT HORNS

Re-entrant horn loudspeakers have been the most extensively used reproducers for public address installations. By using a folded air column, they provide good bass response in a unit that is a fraction of the length of a comparable straight trumpet. But they still suffer from the same disadvantages of narrow polar distribution and high harmonic distortion found in straight trumpets. An additional fault of the re-entrant horn is that it reduces high-frequency transmission by cancellation in the air column when the dimensions across the bends in the air column are of the same order of magnitude as the wavelength of the sound. In the average re-entrant horn, this begins around 3500 cps.

Since the re-entrant horn is so widely used, data obtained with a typical horn are compared in this paper with the CDP data. The horn and driver unit combination used to obtain the data published here is one of the largest selling combinations in the re-entrant horn field at the present time. The horn has a 150-cps cutoff and a circular bell diameter of 20 in. The air column length is 42 in., and the over-all length with the driver unit is 19 in. Its weight is 13 lb.

THE COMPOUND DIFFRACTION PROJECTOR

The compound diffraction projector (CDP) was designed to fulfill the need for a light, compact, inexpensive public address loudspeaker which can provide a widely dispersed, high-quality signal. The CDP consists of two horns which are coupled to opposite sides of a single diaphragm. Each horn is designed for optimum reproduction of a specific frequency range. A small tweeter horn is used for high frequencies, and a re-entrant horn is used for the low frequencies. Figure 3 shows the physical arrangement of the CDP. It is 20 in. long over-all, including the driver unit, and has a 10¾-in. by 20¾-in. rectangular mouth. The total

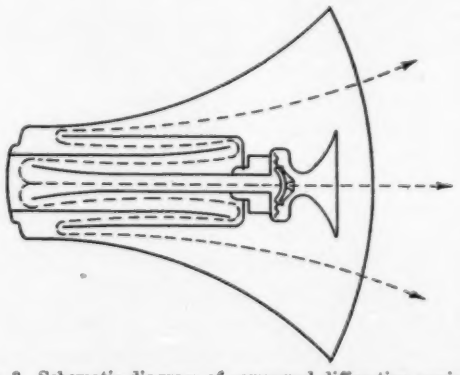


FIG. 3. Schematic diagram of compound diffraction projector.

[2] F. Massa, *J. Acoust. Soc. Amer.*, 8, 130 (1936).

weight with a driver unit is 12 lb. The use of four air column sections in the re-entrant horn permits mounting the driver unit and tweeter horn in front and also provides a longer air column length than can be obtained from three-section re-entrant horns of comparable over-all dimensions.

For greatest sound output, the impedance presented to a diaphragm by a horn should equal the mechanical impedance of the diaphragm. Generally, diaphragms are mass controlled for most of their frequency range, and, therefore, the mechanical impedance increases with frequency. The impedance presented to the diaphragm by the horn also increases as the size of the horn throat is reduced. Therefore, a smaller throat should be used for high-frequency reproduction than for low-frequency reproduction. The throats of the two horns used in the CDP are chosen for maximum output in the frequency range in which each horn operates. Since the frequency range is divided between two horns, the throat dimensions represent less compromise than in the case of a single-horn loudspeaker.

The crossover between the woofer horn and the tweeter horn is obtained by entirely acoustic means. At frequencies well below the cutoff of the tweeter horn, only the woofer is radiating, since the radiation resistance of the tweeter is negligible. At frequencies above the crossover point, a cavity between the diaphragm and the throat of the woofer horn, which acts as a capacitor shunted to ground, effectively decouples the diaphragm from the horn; meanwhile, the tweeter horn is being operated above its cutoff and is therefore radiating. Figure 4 shows the axial response curves for the re-entrant horn and the CDP.

In order to obtain a maximum of bass response with a minimum of size and expense, the re-entrant horn of the CDP is made with a 100-cps taper and a comparatively small mouth. If a single projector is used by itself away from building walls and other surfaces, its bass response is comparable to that of a re-entrant horn of similar size down to the point where the response of the re-entrant horn starts to drop off rapidly. But the response of the CDP continues below this point, owing to its lower rate of flare. If it is desired to take full advantage of the 100-cps taper, the CDP may be mounted with its mouth next to a wall or ceiling or on the floor or ground, wherever a surface may effectively increase the area of the mouth. This permits the person who makes the installation to utilize the acoustic loading properties of the location. When added bass response is desired in open space (mounting on poles, hanging by wires, etc.), it may be obtained by mounting two or more CDP's close to each other in order to obtain mutual loading. Since the mouths of the CDP's do not have to be in the same plane to obtain mutual loading, the array may also be arranged to provide improved polar distribution.

One of the most noticeable improvements in the CDP over the re-entrant horn is its extended high-frequency response. By avoiding energy-cancelling re-entrant sections and by using a horn which is specifically designed for high-frequency reproduction, the high-frequency response of the CDP is made comparable to that of a good-quality tweeter. A comparison of the response of the re-entrant horn and the CDP between 1000 and 3000 cps will show that the re-entrant horn is about 4 or 5 db higher in level than the CDP. But, since these are axial response curves, before judgment is passed on the relative efficiencies of the two units, polar responses must be considered.

Figure 1 shows the polar response of the re-entrant horn. It may be noticed that the polar response is good for the frequencies having wavelengths that are large compared to the diameter of the horn mouth. But, as the wavelengths become shorter, the sound output is concentrated more on the axis. These curves indicate why the straight trumpet and the re-entrant horn are best adapted only for applications where it is necessary to project sound over long distances or to a very small audience. But even in these cases, there are the factors of limited high-frequency response in the re-entrant horn and distortion in both the straight trumpet and re-entrant horn that make them undesirable.

Both horns in the CDP are designed to utilize diffraction in order to spread the sounds they reproduce. In this manner they resemble the familiar diffraction slit used in optics. When the width of a slit is small compared to the wavelength of the energy that passes through it, that energy is dispersed greatly in the direction of the short dimension, or width. Therefore, the mouths of both horns are made with one dimension which is short compared to the wave-

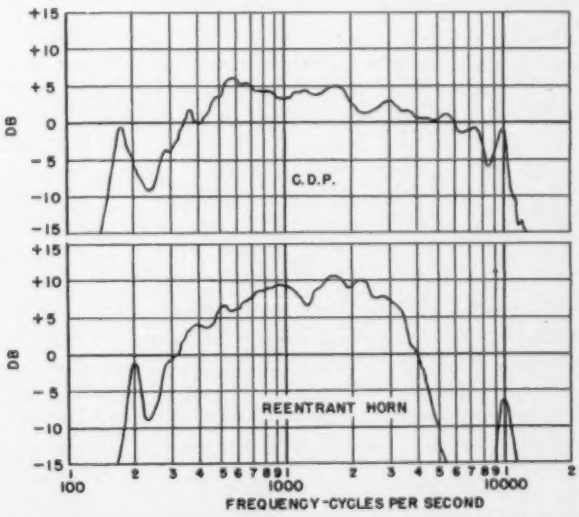


FIG. 4. Axial frequency response curves of compound diffraction projector and re-entrant horn.

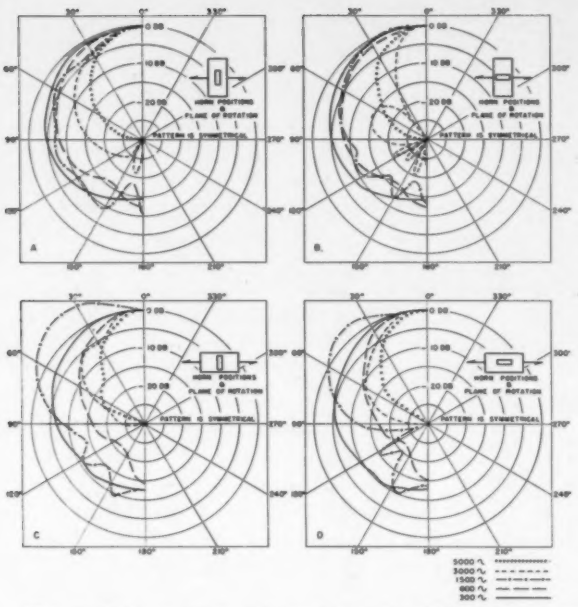


FIG. 5. Polar response patterns of compound diffraction projector.

length of most of the frequencies it passes. In order to provide the greatest versatility, the CDP is constructed so that the bass horn may be mounted with its short dimension horizontal or vertical and the tweeter horn may be rotated to any position. By varying the positions of the two horns, polar patterns for various applications may be obtained. Figure 5A shows the horizontal polar response with the short dimensions of both horns horizontal. This arrangement provides the smoothest and most uniform polar pattern and is best for general usage. By rotating the tweeter horn 90°, the pattern shown in Fig. 5B is obtained. The narrow 3000-cps response is useful in preventing feedback when a microphone must be used in front of a projector. In both of the above sets of patterns, since the woofer horn was not rotated, the 300- and 600-cps patterns did not change. Unusual high-frequency patterns are observed in the plane of the long dimension of the woofer horn. Figures 5C and 5D show two such patterns. The large high-energy loops are due to widely spread sound from the tweeter horn which is reflected from the inner walls of the woofer horn and arrives at the point of measurement in phase with sound that has come directly from the tweeter horn. Responses of this type are desirable when it is necessary to project sound into the corners of a room from a single projector mounted in the middle of the opposite wall, or where the audience is in a rectangular configuration.

Reference to the polar patterns of the CDP compared to the re-entrant horn shows the absurdity of trying to determine the efficiency or usefulness of a loudspeaker from the axial frequency response only. The axial response curves show about a 4- to 5-db advantage for the re-entrant horn compared to the CDP at 3000 cps. But in all the polar patterns, the CDP is only about 10 db down at 3000 cps 60° off the axis whereas the re-entrant horn is down about 25 db. An even greater difference exists at 1500 cps. When total energy output is considered, the CDP is more efficient than the re-entrant horn.

As mentioned previously, high intensity reproduction with a horn at frequencies that are far above the cutoff frequency of the horn will result in a great amount of distortion. In Fig. 2 are plotted the percentages of harmonic distortion *vs* frequency for various amounts of input power for the re-entrant horn and the CDP. Although both the second and third harmonics were used for these measurements, the distortion consisted mainly of the second harmonic, as predicted by theory. As an added check on the theory, a driver unit which had less efficiency in the frequency range measured was tried in the re-entrant horn. The distortion was noticeably reduced. From the foregoing it is shown to be impossible to obtain low-distortion, high-level reproduction in the middle and high frequencies with the usual size of re-entrant horn or straight trumpet. This same distortion will also be produced by large multicellular horns. Since with a CDP the high frequencies are reproduced with a horn that has a relatively high cutoff, such distortion is kept to a minimum. The gradual reduction in distortion with increase in frequency is due to a reduction in pressure at the throat of the horn caused by increasing diaphragm impedance and decreasing shunting impedance of the chamber in front of the diaphragm.

Distortion measurements were made using a CDP at 20 watts at various frequencies from 2000 to 3000 cps. These measurements indicated about 2% distortion. The driver unit was then removed from the CDP and placed on a re-entrant horn (150-cps cutoff), so it was driving the horn from the "high" end of the unit. Distortion measurements were again made at 20 watts between 2000 and 3000 cps. This time the distortion was about 10%.

By utilizing the acoustic advantages that can be obtained from a compound horn loudspeaker, the CDP provides a signal that has improved frequency response and polar distribution with lower distortion in an inexpensive, lightweight unit.

JOURNAL OF THE AUDIO ENGINEERING SOCIETY JANUARY 1954, VOLUME 2, NUMBER 1

The Philosophy of Amplifier Equalization*

H. H. Scott
Hermon Hosmer Scott, Inc., Cambridge, Massachusetts

THE EARLY PHONOGRAPH

THERE IS little similarity in sound between the modern high-fidelity system and the early phonograph. Nevertheless, the average "audiophile" uses his high-fidelity system mainly for playing phonograph records which differ only in seemingly superficial details from the earliest phonograph records. Many times in the improvement process the advertisements have acclaimed that the ideal has been attained. As we listen to the best of modern recordings, it sometimes is hard to believe that further improvement is possible. In spite of that, the best of the early LP's, which seemed remarkable in their day, sound pallid compared to today's routine recordings.

The early phonograph industry was based upon art rather than science. All the power to vibrate the cutting stylus was supplied acoustically by the performers. To record, a singer bellowed into a horn at the small end of which was a diaphragm which actuated the recording stylus, cutting its groove on soft wax. Orchestral instruments were "souped up" with additional resonators, horns, and other contraptions to make them louder, with an effect upon quality which would have made the instrumental timbre unrecognizable even if the recording had been good. For reproduction, a similar system operated in the other direction. The rotating record vibrated the needle which in turn actuated a diaphragm coupled to a horn. Since there were no vacuum tubes, there were neither electronic amplifiers nor electronic measuring equipment. The designers of these early systems therefore experimented with the essential mechanical elements of the system, bucking one resonance against another and attempting to obtain the best over-all result as judged by the ear.

That the phonograph was accepted even then as an artistic medium and that the industry reached a gigantic size for those days are proof more than anything of the imagination of the average listener, which succeeded in re-creating in his mind, from the wraithlike reproduction, a satisfying facsimile of the original performance. The music lover of today, however, demands far more than a stimulant to his imagination. He insists, in fact, upon reproduction practically indistinguishable from his conception of the original performance.

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.

It is not the province of this paper to discuss monaural listening versus binaural or stereophonic, or to cover the various acoustic problems involved in the placement of microphones and loudspeakers. It should be pointed out, however, that all these factors enter into the realism of the final reproduced sound, and since all may possibly detract from the realism, it is of vital importance that the electronic and recording links of the system be as nearly perfect as possible and contain certain compensating features. Neglecting for the moment the acoustic elements of the system and any necessary compensation for them, the ideal will be reached when the voltage applied to the loudspeaker terminals is an exact replica of the much smaller voltage obtained from the microphone. The design and manufacture of amplifiers with negligible distortion is highly developed so that the most likely variations or distortion will occur in the recording and reproducing processes.

THE NECESSITY FOR EQUALIZATION

In the interests of simplicity and interchangeability, it is general practice to make every link in a communication system "flat," that is, having equal response at all frequencies within the desired range. If parts of the system are not flat, the over-all response cannot be flat unless one part compensates for another. In dealing with the usual processes for recording and reproducing, however, we are not dealing with flat systems. (Although at the moment we are merely concerned with the disk recording, the same general principles apply to other types of recordings, as, for instance, magnetic tape.)

The early acoustic phonographs had a response that, in its limited range, tended to be of the constant-velocity type. In other words, a given acoustic sound pressure would produce approximately the same stylus velocity over a given range of frequencies. The reproducer worked in the same manner; a constant velocity of the needle tended to produce a constant output. Such systems, however, were not flat, or even remotely so, over any but the most restricted range, since resonances were necessary to maintain a satisfactory degree of sensitivity.

With the modern phonograph recording, the sensitivity is increased in both recording and reproduction by interposing vacuum-tube amplification between the acoustic and mechanical elements of the system. This makes possible the

use of transducers, that is, microphones, recorders, pickups, and loudspeakers, free of the more serious resonances and consequently capable of operation over a wide range of frequencies. The usual disk-recording head, like the old acoustic recorder, naturally has a constant-velocity response. With such a response, the actual displacement of the cutting stylus is inversely proportional to the frequency, and consequently the sound as recorded on the record is not like an oscillogram of the original acoustic wave form but rather is the integral of the original wave form. Since the actual recorded amplitude is then inversely proportional to the frequency, it is obvious that at low frequencies the amplitude will become very high indeed, which would require very wide groove spacing if one groove were not to cut over into the next.

GENERAL TYPES OF PLAYBACK CHARACTERISTICS

This was the first problem encountered when the designers of the early electric recorders attempted to increase the frequency range over that of the earlier acoustic recorders, and their solution was simple. Below a certain frequency, called the "turnover" frequency (now often called the "transition" frequency) they reduced the response at the rate of 6 db per octave, converting the constant-velocity curve into a constant-amplitude curve. The usual transition frequency was 250 or 300 cps, and this type of recording characteristic was standard for many years. The curve marked EUR in Fig. 3 shows the theoretically correct playback characteristic for this type of recording.

Many of the early electric pickups had internal compensation providing the proper bass boost on the assumption they would be used with an amplifier which was essentially flat. One common type, for instance, utilized an arm shaped like a cobra's hood and containing weights. With such an arrangement, sufficient arm resonance was introduced to provide approximate compensation over a limited range for the reduction in recorded bass.

Another defect of the early phonograph was surface noise. Although many devices were developed to reduce this, obviously the most desirable procedure is first to obtain the optimum signal-to-noise ratio in the recording. The same inverse relationship between amplitude and frequency which necessitated limiting the amplitude at low frequencies caused the opposite difficulty at the high-frequency end; the high-frequency groove variations were so minute as to be comparable with the normal noise level of the record. To reduce the noise, many pickups, particularly of the crystal variety, were operated in such a manner as to reduce the high-frequency response. A logical development then was to increase or pre-emphasize the high-frequency response in the recording process, bringing the high frequencies to a level where they would override the noise. Such recordings could then be reproduced with a pickup or system having a drooping high-frequency characteristic, thus obtaining a flat over-all characteristic between the input of the recorder and the output of the reproducing system, at the same time greatly reducing the background noise. The AES playback curve shown in Fig. 1 shows a typical characteristic of this type.

The fundamental recording curve was therefore primarily composed of three sections, bass and treble ranges sloping at a rate approaching 6 db per octave, and a narrow midrange which was approximately flat. The reproducing or playback curve should, of course, be the exact inverse of the recording characteristic, which implies a low-frequency response sloping upward, as the frequency is reduced, at a rate of 6 decibels per octave. Naturally, this increase in low-frequency sensitivity greatly exaggerates turntable rumble and, in fact, if carried to an extreme, can cause the system to overload merely on the voltage produced by any eccentricity of the record. Many companies and organizations, therefore, have added so-called bass pre-emphasis to the recordings, which means merely that the low-frequency attenuation is leveled off at a definite point and returns to a constant-velocity curve. This limits the necessary bass boost in the reproducing system with a desirable reduction in rumble and other low-frequency interference. The Columbia playback curve shown in Fig. 1 is of this general type.

With the advent of professional-quality pickups allowing low stylus pressures and capable of tracing satisfactorily over wide frequency ranges, it became apparent that equalization could not be satisfactorily built into the pickup without adversely affecting record wear and greatly complicating the pickup and arm design. Since the desired playback curves are easily simulated by simple RC circuits, the logical place for the equalization is in the preamplifier, which is required with practically all wide-range pickups. By this means, exact equalization can be attained and maintained without resort to complicated mechanical systems.

Unfortunately for the user of records, the recording companies have never agreed among themselves upon what is the best over-all characteristic. The result has been that different companies and organizations have used different recording curves, and the records must therefore be played back with different playback equalization. This resulted in the demand, first from broadcast stations, and more recently from music lovers, that variable equalization be provided as an integral component of amplifiers designed for playing transcriptions and records.

EQUALIZERS AND CONTROLS

Early broadcast station equalizers had three or four positions, including such curves as the then-current Orthacoustic and the NAB, and at least one position for playing

shellac records. With the demand for greater fidelity, however, and with the advent of other recording characteristics, it became apparent that so few positions did not provide sufficient flexibility. The problem of providing this flexibility with simplicity of control has been approached in a number of ways.

Separate equalizers, as first used by broadcast stations, have in general a combination of the following disadvantages: excessive cost, if inductors are required; undesirable loss, decreasing the already small voltage available from the pickup, thus necessitating an increase in amplification and consequent noise level; and reliance upon the internal impedance of the pickup for correct operation, thus limiting each equalizer design to only one type of pickup. Since most professional-quality pickups are magnetic, including such types as variable reluctance, moving coil, and moving iron, and since such pickups naturally have a true constant-velocity response, it is obvious that equalization within the amplifier without dependence upon the internal impedance of the pickup is by far the most versatile arrangement. Such a preamplifier designed for constant-velocity pickups can be used with practically any such pickup on the market and the equalization will be correct, assuming only that the pickup itself is properly loaded in accordance with the manufacturer's instructions for a flat, constant-velocity response.

Recently, other pickups have appeared on the market, including, for instance, one which operates on an FM principle. This particular pickup provides a constant-amplitude output which may be readily converted to constant velocity by means of the simple RC network. Many of the newer high-grade preamplifiers have this network built in, providing correct equalization for either constant-velocity or constant-amplitude pickups.

The present type of high-fidelity amplifier with exact equalization for a large number of playback characteristics is a relatively new device and has become popular only since the record manufacturers have made a conscientious effort to adhere to published curves. Previously, the actual equalization, even among records from a single manufacturer, varied considerably, and the only practical solution was to provide a single, average playback characteristic supplemented by extremely flexible tone controls or variable equalizers allowing considerable variation in either direction from this average characteristic. Such amplifiers allowed the user to obtain approximately equal tonal balance from a wide variety of records of varied origin.

The next step (1949) was to provide, in addition to the tone controls, step-by-step high- and low-frequency equalizers, commonly termed "rolloff" and "turnover" controls. With such controls, a number of standardized playback characteristics can be synthesized accurately, leaving the tone controls only for additional compensation as, for instance, unusual acoustic conditions.

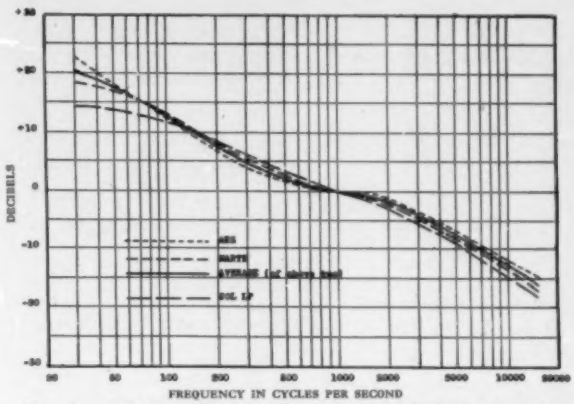


FIG. 1. AES, NARTB, and Columbia LP playback characteristics. One of these curves will correct for practically any common current LP record. Since AES and NARTB are quite similar and have specified limits of ±2 db, the curve marked "average," which is the mean of these two, is an acceptable substitute for both.

In the interest of producing equipment of maximum usable flexibility but selling in the minimum price range, a recent study has been made of the actual number of curves required to play all current LP recordings; the results are shown in Fig. 1. Although standardization has not been reached, it has obviously been approached much more closely than before. The AES and the new NARTB curves are fairly similar except in the extreme low-frequency range, and, since each is specified with a tolerance of ±2 db, it is possible to draw a single curve falling within the limits of both specifications over the entire range. This is the solid line marked "average" in Fig. 1, which is actually the mean of the AES and NARTB curves. Except perhaps in the most elaborate installations, this single curve is entirely adequate for playing recordings made to either one of these characteristics. (The RCA New Orthophonic curve is the same as the new NARTB.)

Perhaps the most common curve for LP records, however, is the original one introduced by Columbia, also shown in Fig. 1. This uses more bass and treble pre-emphasis in the recording than any other common curve and consequently requires less bass and treble response for the playback curve. Let us then include this curve in addition to the above-mentioned "average," and we cover a large proportion of all the new records. Furthermore, if the equalizer is of the two-control variety with separate turnover and rolloff controls, combination of the Columbia LP turnover with the "average" rolloff provides almost an exact match for London records.

It is also desirable to be able to play older and foreign records, including 78's. Consequently another curve should

FIG. 2. Low-priced transcription amplifier combining high flexibility with a minimum of cost; individual high- and low-frequency adjustments following Columbia LP, mean of AES and NARTB, and EUR characteristics allow synthesizing of nine different playback curves matching closely most records.

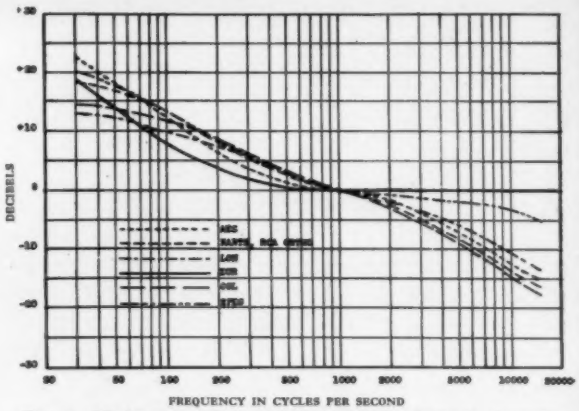


FIG. 3. Minimum number of individual LP playback characteristics required for present-day practice. (Also available on the single equalizer control are other playback characteristics for 78-rpm records in addition to the EUR curve. See Fig. 4.)

be added to the equalizer, namely that shown as EUR in Fig. 3. This has a turnover of approximately 250 to 300 cps and a flat high-frequency response. Naturally, the two halves of the curves may be combined with other curves to produce other characteristics. For instance, the EUR low end and the LP high end provide a perfect match for Columbia shellacs.

Figure 2 shows a low-cost amplifier with these equalizer controls. The two controls marked "turnover" and "rolloff" with three positions each provide a close match within high professional standards for practically any current recording and most older recordings. In those few cases where an exact match cannot be obtained, wide-range tone controls are also available for intermediate adjustments. The flexibility of this type of amplifier, therefore, has proved more than adequate for all except the most demanding. Although this equalizer was originally presented nearly four years ago in high-priced amplifiers and has hitherto been available only in that price class, manufacturing and design economies plus the inherent simplicity and low cost have brought the price down so that it is available now in the lowest price brackets.

In the higher price ranges there is, however, a considerable demand for an amplifier which is simpler to control—one with only one equalizer switch. Since this eliminates the possibility of combining the low end of one characteristic with the high end of the second to obtain a third, it is obvious that many more switch positions are necessary, with a consequent increase in cost. Also, in this price range users expect exact equalization for all recording curves, not merely within specified tolerances but following exactly the design objectives. Such amplifiers have been available for over two years and actually represent the greater portion of the sales to date in high-quality amplifiers. Figure 3 shows some of the typical curves provided on a recent model. It will be noticed that an exact match is provided for AES, NARTB (RCA New Orthophonic), London, and Columbia. An additional curve marked "Spec" is also provided for playing early LP records which did not have as effective

FIG. 4. Preamplifier having single equalizer control providing exact match for practically any current LP record and most older records.

high- or low-frequency response as many of the current types. This characteristic has been found to improve such records immeasurably. In addition, the EUR characteristic is provided for old shellac and European records and several other curves not shown for playing different types of American shellac records.

Figure 4 shows a typical equalizer-preamplifier incorporating this type of control. The great advantage of this equalizer is simplicity of operation. The user need merely set a single control for each type of record to be played. Among nontechnical music lovers this is very important. It is difficult for many of them to accept two controls when the same result can be accomplished with one, and they are willing to pay the extra price for the added circuit complexity and the more elaborate switching.

There is, however, another class of audiophile who wants nothing short of the maximum possible flexibility, and to please him still another method of control has been devised,

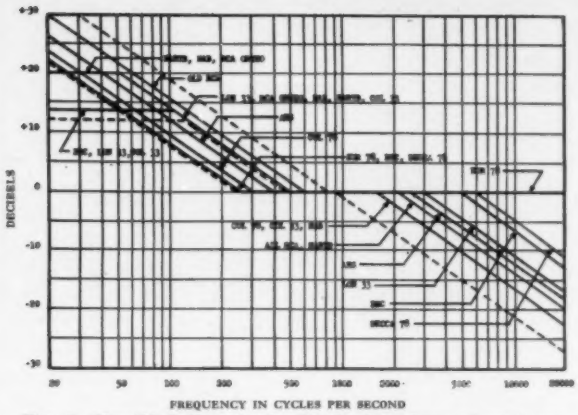


FIG. 5. Simplified diagram showing basic makeup of most common reproducing curves. Broken lines show maximum range of continuous controls on Type 121-A Dynaural equalizer-preamplifier.

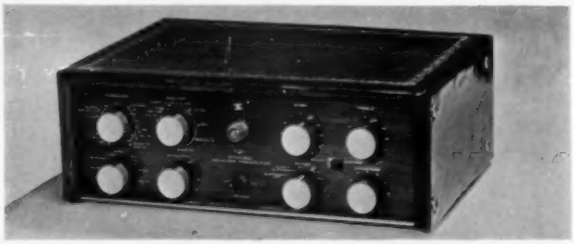


FIG. 6. Equalizer-preamplifier incorporating double continuous equalizer controls and Dynaural noise suppressor. So far as is known, this is the most flexible and adaptable preamplifier available.

namely the continuous equalizer. Although there have been many playback curves in the past, and there are still a number of different ones in use, most of them can be analyzed simply in terms of bass turnover and high- and low-frequency rolloff, as shown in Fig. 5. This figure, in the interest of simplicity, has been drawn with straight lines and sharp angles. Naturally, the actual response of the system will round off the sharp angles and alter the slopes in the vicinity of the angles, but Fig. 5 may be considered as a sort of skeleton showing the bases on which the playback curves are built up.

Figure 5 also shows the ranges over which it was desired to be able to vary the response to include everything from the old European and 78-rpm curve (constant velocity with a 250-cps turnover) to practically a constant-amplitude curve, including all the accepted curves, either with or without bass rolloff, and also intermediate curves. It was further determined that only two controls should be used, one for treble and one for bass; to this limitation there was only one answer, namely that the bass control have a double range including both simple constant-amplitude bass characteristics and those with the bass rolloff.

A commercial amplifier incorporating this most flexible of all equalizers is shown in Fig. 6. The turnover control which adjusts the bass response when set at midposition provides an 800-cps turnover. As the control is turned clockwise, this turnover decreases uniformly to 250 cps, providing an exact constant-amplitude bass response at all intermediate points. If, however, the control is turned counterclockwise from the center position, the turnover decreases rapidly to 500 cps and then remains fixed. Further counterclockwise rotation varies the bass rolloff, providing an exact match for NARTB, RCA New Orthophonic, old NAB, London, Columbia, BBC, and other curves. It is very important that these *two* types of bass response be provided. For instance, among common, widely used curves, the AES at 30 cps requires 9 db more response than the Columbia LP. So far as the high-frequency rolloff control is concerned, the design is less critical, but a special tapered variable resistor is required to spread the desired range fairly evenly around the control, and a switch attached to the control removes all rolloff for a true constant-velocity high-frequency response.

It would appear, therefore, that this type of equalizer with its two continuous controls, its high degree of flexibility, and its ability to synthesize practically any playback curve provides practically all that the most critical audiophile can desire. Whether it will be more popular than the simple control having a single switch with a large number of positions cannot be told at this time, but the initial response to the original announcement indicates that there is a large latent demand for this type of equalizer.

There are, however, so many classes of customers for high-fidelity and professional sound equipment that it seems inadvisable to limit the products of any one manufacturer to a single type or model. We are at the present time, for instance, producing no fewer than four different types of equalizers, including the simple step-by-step two-control type, the elaborate, continuously variable two-control type, the simple combination of wide-range tone controls with a single average equalization curve, and the simplest and most popular, the single switch providing a large number of equalizer positions. Perhaps in the future, as the trend toward standardization increases, the number of necessary models will decrease. There are, however, many records in the field which were recorded several years ago, and which will be sold for years to come, so that standardization and the resulting simplification in playback equalizers must necessarily come even more slowly than standardization among the record manufacturers.

The Significance of High-Frequency Intermodulation in Audio Equipment*

EMORY COOK
Cook Laboratories, Inc., Stamford, Connecticut

THE ORDINARY kind of intermodulation measurement has become thoroughly familiar to all of us during the past several years. Its theory and its correlation with listener evaluation and acceptance have been well covered in the literature. At the same time, many of us must have wondered what would happen if we were to apply high-frequency intermodulation signals instead of the usual 30 to 400 cps (for the low frequency) and 6000 to 10,000 cps (for the high frequency).

Unfortunately, for two frequencies logarithmically close together in the spectrum, ordinary intermodulation metering equipment does not function. The demodulation and filtering circuits do not apply.

The question of what happens in high-frequency intermodulation is of particular interest because of a strange and devilish coincidence. The coincidence revolves around two things: (1) the Fletcher-Munson curves of ear power sensitivity, which indicate that the ear is in a peculiarly good position to hear weak components of signal in the range above 1000 cps; and (2) the astonishing fact that musical harmonies are ordinarily played in thirds or fifths; in the two octaves from 500 to 2000 cps will ordinarily lie the melodic line.

The significance of this second point is that with voices, orchestral or otherwise, having typical second, third, and fourth harmonic content, the overtone content of a basic chord or of a melody and countermelody will often be distributed through the high-frequency spectrum with intervals of 1000 to 2000 cps between successive major components. On a quantitative basis, the frequency of occurrence of 1000 to 2000 cps as the interval between predominating harmonic overtones is highest. Thus their tendency to intermodulate to produce quadrature resultants in the 1000- to 2000-cps range is also predominant. This is partly the fault of our voice and instrument overtone complexion, that is, the distribution of harmonic overtones, and partly the fault of the traditional harmonic structure. Incidentally, modern untraditional harmonic structures appear to be still worse.

When two predominating overtones (such as 2610 and 5220 cps on the musical scale) of an octave fundamental (870 to 1740) intermodulate, they would appear to have a difference product of 2610 cps—in true harmonic relation to the fundamentals—provided that the octaves are in tune. However, let a third or a fifth be thrown in for harmony, and the overtone intermodulation products appear at 452.26 cps, 904.52 cps, etc., inharmonically related to all components of the original signal, in the range of maximum power sensitivity of the ear, and distinctly unpleasing.

Thus it is apparent that, the wider the range of the audio system, the more dangerous it is to have appreciable high-frequency intermodulation, for the intermodulation products —the *results* of distortion in the upper range—tend to fall into a range of high power sensitivity of the ear. Wide range and low distortion do not necessarily go hand in hand for audio systems. Many wide-range systems are extremely distortive. We do not even have to have a wide-range loudspeaker to hear the unpleasant effects of high-frequency intermodulation. Wide-range records or other program material played through a good cartridge into an audio system of amplifiers and speakers that is distortive but limited in range sound bad because of the spurious midfrequency components added by high-frequency overload of the amplifier, or by voice coil rubs in the loudspeaker. This is the true explanation of the well-known fact that good program material often sounds worse than limited program material when played on a limited system. Corollary to this line of thought, it is always a good idea to have the *frequency* response of a system either the same as or slightly poorer than the *power* response *vs* frequency. In almost all commercial amplifiers, the opposite is true.

TABLE I

Percentage high-frequency speakers found with voice coil rubs or other nonlinearity	35
Number of preamplifiers found with overload "N's" exhibited as result of too much gain ahead of first volume control (treble wide open)	4
Number of cartridges showing "N" because of inadequate rated tracking pressure	4
Cartridges of given manufacture displaying "N" over 5% (logarithmic basis) of range 20 to 4 kc	
Mfr. 1	None
Mfr. 2	10%
Mfr. 3	25% (crystal)
Mfr. 4	100%

Note: High moving mass armatures do not produce "N's" at higher frequencies due to deformation of vinyl. At these frequencies they also do not reproduce the carrier itself.

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.

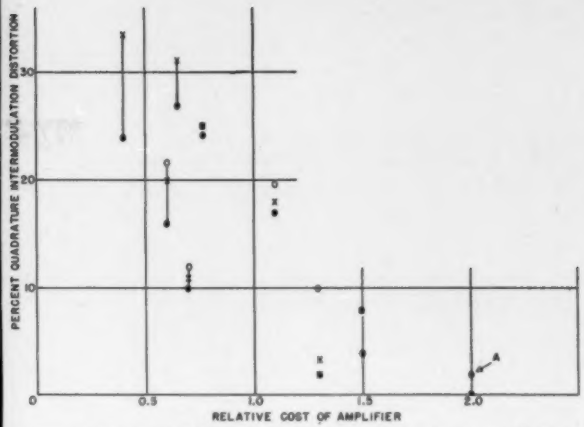


FIG. 1. Constant-difference frequency I.M.D. signal applied at: ○, rated power output (10 kc); ×, one-half rated power output; ●, one-quarter power output. Unit cost refers to a net price of $5.00 per watt for 10-watt ratings and above. *A* refers to special Cook design used for demonstration and exhibit, having both negative current and voltage feedback to achieve bona fide generator impedance at output.

The "N-A" method for presenting high-frequency intermodulation signals depends upon having two high-frequency signals simultaneously, related by the rule that the two frequencies when subtracted one from the other shall have a constant difference. Thus, we may take two oscillators, one at 20,000 cps, the other at 19,000 cps, and sweep them down to perhaps 4000 cps and 3000 cps, respectively. In so doing we shall cause them to be always 1000 cycles apart. If at some point in their journey from 20 kc to 4 kc there is distortion in the system under test, the quadrature resultant will, of course, contain the difference frequency, 1000 cps.

Rather than require the user to operate a calibrated piece of equipment to determine the relative magnitude of the 1000-cps resultant, it is possible to interrupt periodically one of the "carriers" and to insert in its place a 1000-cps signal whose amplitude is prearranged to be a certain percentage of the carrier amplitude. This interruption can translate the information conveniently and in a readily recognizable form if it is done in the form of a constantly repeated code letter "A" (dot-dash), whose interstices form code "N's." Thus, if the 1000-cps intermodulation resultant present when both carriers are on is of the same loudness as the coded 1000-cps "A," the distortion "N's" and the coded "A's" will complement each other to form a steady tone (with keying clicks). If the distortion predominates, "N's" will stand out. If the distortion is lower than reference "A," the "A's" will emerge.

There are two reasons for putting this signal on a record. First, the coded signal and synchronized sweeps are difficult to arrange, and they require a lot of equipment. The other reason is that a good percentage of troubles are found in the cartridges.

In using the "N-A" test record, perhaps the first thing to do is to listen for coded needle-talk from the cartridge. If one hears "N's" from the cartridge with all the amplifying equipment shut off, it is hard to escape the conclusion that the cartridge is not tracking. Tracking is a function of the vertical pressure of the stylus on the groove and the motional impedance of the moving armature referred to the tip. For any given high frequency, increased vertical tracking pressure is required to "track" increasing recorded volume levels. The higher the level, the higher will be the necessary tracking pressure, until the point comes at which the unit pressures on the vinyl compound are so high in tons per square inch that it gives way to the needle impact. High-frequency intermodulation testing may be used to determine bona fide tracking pressures.

In amplifiers and preamplifiers this testing method readily determines at what operating level overloading of high-frequency signals takes place, and what constitutes a maximum safe setting for treble and volume controls in a home music system. In many cases it will be found that a rather low volume and treble boost setting produces "N's." The effect of having too much gain ahead of the volume control or treble boost circuit will be evident. By means of volume control adjustments at the various points in a system it is possible to determine which unit is offending, and the speaker voice coil rub can be established by the process of substitution of speakers or by simply removing the high-frequency speaker of a multiple-unit speaker system from the circuit. The tell-tale 1000-cps signal will still be audible on the low-frequency speaker if the fault is in the amplifier.

The 2% standard of reference set in the Series 50 record is not to be compared with what has come to be associated with "2%" as applied to standard intermodulation performance. It is a fairly good standard of performance in the high frequencies, but not extreme. In the hands of the non-technical user who is without even so much as an ac voltmeter, it is capable of doing a healthy job of supplying fairly specific information and improving standards of acceptance, as well as generating a discriminating taste for the better equipment.

New Developments and Applications of Printed Circuits*

ARTHUR W. KELLY, JR.
Photocircuits Corporation, Glen Cove, New York

New manufacturing methods will be briefly discussed. This will be followed by a summary of the latest achievements in etched circuit techniques, including examples, samples, and explanations of applications.

WHY HAS the use of etched circuits increased every year? This has come about because of several reasons. The experience acquired by engineers on printed circuit applications, the increased circulation of literature on printed circuits, and lower costs due to improved production techniques have all been important factors. This increased usage, however, is an outgrowth of just one fundamental principle. The electronics industry is approaching the limit of improvement of hand wiring and soldering methods. There is, therefore, widespread realization that automatic assembly must be used in order to cut the high labor costs of hand wiring. The first step toward that end is the use of printed circuits and dip (one-shot) soldering wherever possible. Conventional wiring costs cannot be reduced much more, but printed circuits costs, which already compete with conventional wiring costs, are declining steadily. In the near future, a large percentage of hand soldering and wiring will probably be eliminated from the electronic industry's production lines.

FIG. 1. Laying out an etched circuit master.

FIG. 2. Piercing and blanking etched circuits.

NEW PRINTED CIRCUIT MANUFACTURING TECHNIQUES

During 1953, two relatively new methods of manufacturing printed circuits on plastic bases were widely advertised. The first process involves the embedding of silver powder in a plastic board through the application of heat and pressure. The desired conductive pattern is produced by placing the master etched or engraved metal plate in a press over the sheet covered with silver powder. After pressing, the silver powder is removed from the areas which were not embedded.

The second method is to electroplate a conductor pattern on a plastic laminate. In this process, sheet plastic is made conductive by the use of a sensitizer. A mask is then placed over this sensitized sheet, and the pattern is electroplated to the laminate. After plating, the sensitizer in the unplated areas is removed. Although these techniques show promise for the future, they have not yet proved to be more economical than the etching processes.

What new achievements were made during 1953? Since several commercial methods of etching foil-clad plastics have been devised, much effort was directed toward solving other problems. Among these is the fundamental problem of how to make connections to etched wiring. Here there are really three connection problems: (1) how to make reliable connections from etched patterns on one side of plastic boards to etched conductors on the opposite side; (2) how to connect staked hardware electrically to etched circuitry economically; (3) how to connect the components and external leads to etched conductors economically and reliably.

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.

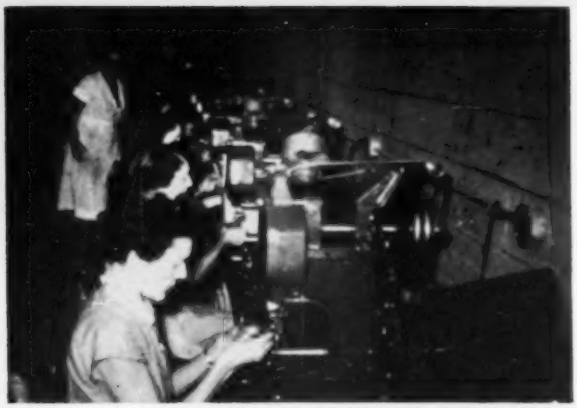


FIG. 3. Eyelets used to be used for crossover connections on two-sided etched circuit.

FIG. 4. Now electroplated holes provide crossover connections on two-sided etched circuits.

The first problem, that of connecting patterns on opposite sides of the board to each other, has been solved by the development of techniques of electroplating the walls of any, or all, holes in the plastic simultaneously when plating the pattern. The copper pattern is often plated to prevent oxidation and to aid in soldering. Plating the walls of the holes not only provides a reliable conductive path between two-sided patterns economically but also provides capillary action in the holes during dip soldering. With solder plating through the holes, leads which were dip-soldered to etched circuits withstood tests of 52 lb of pull. At this point, the solder joint held, but the wire lead broke.

The second problem, that of connecting hardware electrically to the pattern after it has been staked to the plastic board, seems to be at least partially solved. Hardware such as turret lugs, eyelets, and threaded studs can be hot tin-coated before being staked. The etched circuit can then be electro-solder plated with 60-40 solder. If the unit is then dip-soldered, the electroplated solder will fuse and fillet to the base of the hardware; if no dip soldering is necessary, however, the hardware may be fused to the etched pattern by the application of heat.

Extensive studies are in progress in an attempt to solve the third problem of connecting heavy components and external leads to the circuit. Several companies now manufacture snap-in tube sockets and i.f. cans especially designed for printed circuits. New hardware for screw terminals and plug-in terminals is already in the development stages. De Jur-Amsco, Winchester Electronics, and other companies are producing plug-in connectors for printed circuit assemblies with as many as eighteen contacts per plug. Much thought and work remains to be done in this field to bring some of the fine ideas already being utilized into products that are within the economic range of a larger part of the electronics industry.

In the line of materials, the search continues. It is hoped that copper-clad plastics will be found with higher bond strengths at high temperatures, lower losses at high frequencies and lower moisture absorption, and if possible, at lower

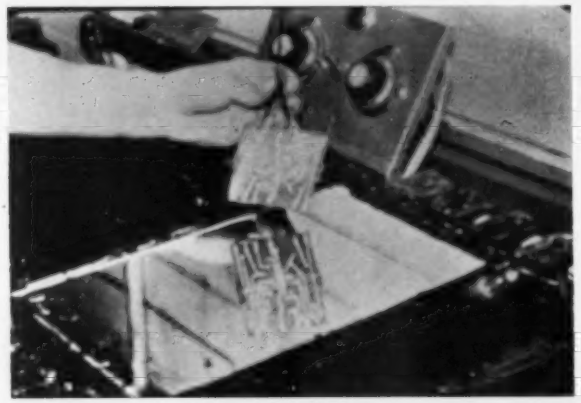


FIG. 5. Dip soldering.

FIG. 6. Mass-produced television antenna crossover circuit.

FIG. 7. Final inspection and shipping.

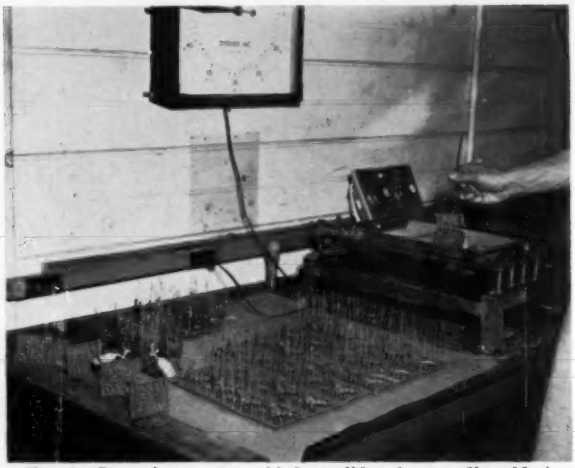


FIG. 8. Removing an assembled amplifier from a dip-soldering bath where all necessary connections between components and conductors have been made.

prices. Recently, an epoxy glass laminate known as Epoglass has become commercially available. It is excellent for high-temperature applications, and its cost is not prohibitive. Laminates such as mylar, polyethylene, and polystyrene show considerable promise also.

New encapsulating or potting materials are being evaluated for printed circuits. Present indications are that this packaging technique not only will solve the moisture problems for applications in wet atmospheres but also may be quite economical. For example, encapsulating a 2-in. by 2-in. etched circuit in an epoxy resin to a thickness of about one-quarter of an inch costs about 10 cents in production lots. Less expensive and superior materials are undergoing laboratory tests.

Where are printed circuits most widely used? Today the radio and television industries use by far the largest quantity of printed circuits. Applications include completely dip-soldered television i.f. strips which sell at a price between $3.50 and $4.50, less tubes. Television antenna cutoff filters and wave traps which sell for 50 to 60 cents completely packaged have become popular. Several five-tube printed circuit radio chassis have been designed that cost between 25 and 50 cents each.

Companies concerned with manufacturing computers, business machines, and other complex electronic assemblies in short or moderately long runs have been in the best position to derive substantial economic advantages through the use of etched wiring. In these applications, not only are high hand wiring costs eliminated, but also much tedious inspection and "trouble-shooting" time is saved. Printed circuit flush-type commutators can perform complex switching operations in these assemblies and usually cost a fraction of their equivalent conventional switch. Printed circuit switches may be designed to withstand more than 50 million wipes without mechanical or electrical failure.

Over the past year, particularly, concerns manufacturing high-fidelity amplifiers and tape recorders have become interested in printed wiring. Besides the obvious economic advantage of printed circuits, these companies have solved the most important problem in high-fidelity equipment, lead dress. One company has designed a four-tube amplifier

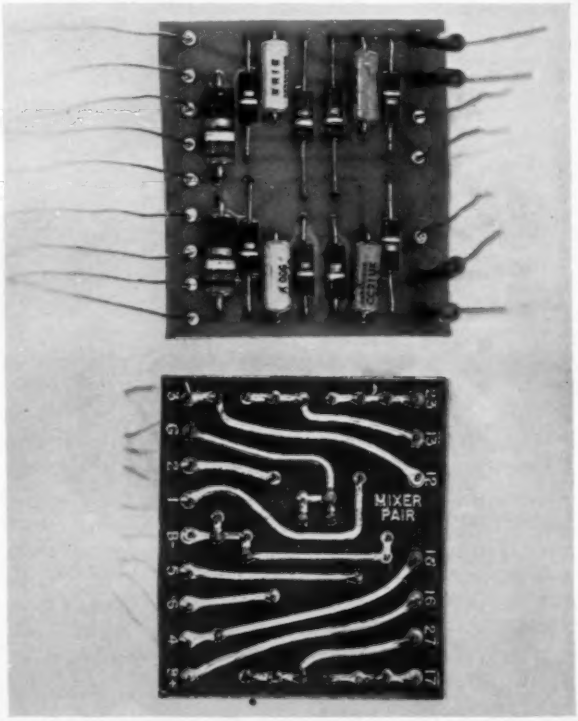


FIG. 9. An amplifier circuit manufactured economically in a short run.

chassis with push-pull 6L6 output that costs them about 38 cents.

CONCLUSION

It may be generally stated that the more components and complex wiring a circuit contains that can be printed, the greater are the benefits derived from etched circuits. However, etched circuits are also being used to advantage in extremely simple devices. This again points up the fact that, although hand wiring techniques have been improved almost as much as possible, their cost is still rising with increasing labor costs. Printed circuits, however, are not only improving in quality but are also decreasing in price.

The *Journal* presents below a discussion of standards for high-fidelity equipment. It is hoped that this material will stimulate interest in establishing a working standard. Further material along these lines will be found in the four papers on nomenclature in this issue.

Comment on these recommendations either in the form of letters to the Editor or communications directly with the Standards Committee is invited. *The Editor.*

High Fidelity — What Is It?

Some Suggestions For a High-Fidelity Yardstick

THERE SEEMS to be so much misunderstanding about the term "Hi-Fi" that it should be redefined in the light of modern knowledge. Originally it was used to express systems which had lower frequency limits of perhaps 80 cps and upper frequency limits of 8000 cps. The distortion commonly tolerated with such systems was "less than 5% harmonic," presumably mostly second, but possibly high order for pentode output stages with little or no feedback. The usable dynamic range was limited to 45 or 50 db, mainly by hum, and hum harmonics plus noise.

As time has passed, the art has progressed so that we now find well-established radio manufacturers advertising amplifiers as flat to 80,000 cps—believe it or not! Nothing is said about the all-important transducer-loudspeaker to non-engineers.

Fortunately, there exists a means for clarifying this confusion by a well-defined set of descriptive terms. It is the serious purpose of this brief note to propose some new terms for the consideration of the AES Standards Committee.

The radio art was faced with a similar problem a few years ago and the terms selected were: LF (low frequency), MF (medium frequency), HF (high frequency), VHF (very high frequency), UHF (ultra high frequency), and SHF (super high frequency).

Perhaps we can take a lead from the above selection and consider the following terms: HF (high fidelity), VHF (very high fidelity), UHF (ultra high fidelity), SHF (super high fidelity). The respective ranges of the above terms might be defined as in the accompanying table.

A component which falls in between would be in the next lower class; for example, an amplifier with a frequency response from 30 to 15,000 cps would be a VHF amplifier, if its IM and square wave (SW) met the requirements for that class.

Term	Frequency Range cps	Distortion	Transient Response	Dynamic Range
HF	80 to 8000 at 3-db points	Less than 10% IM between any two test frequencies between 80 and 8000 cps under rated maximum level	Pass a 1000-cps square wave without ringing and less than 15% overshoot with less than 60 μsec rise time from 10 to 90%	At least 45 db
VHF	40 to 12,000 at 3-db points	Less than 5% IM between any two test frequencies between 40 and 12,000 cps under rated maximum level	Pass a 400-cps square wave without ringing and less than 10% overshoot with less than 40 μsec rise time from 10 to 90%, tilt less than 10%	At least 52 db
UHF	20 to 16,000 at 3-db points	Less than 3% IM between any two test frequencies between 20 and 16,000 cps under rated maximum level	Pass a 200-cps square wave without ringing and less than 5% overshoot with less than 30 μsec rise time from 10 to 90%, tilt less than 5%	At least 60 db
SHF	15 to 20,000 at 3-db points	Less than 2% IM between any two test frequencies between 15 and 20,000 cps under rated maximum level	Pass a 150-cps square wave without ringing and less than 3% overshoot with less than 25 μsec rise time from 10 to 90%, tilt less than 3%	At least 65 db

There are some fine points as to how all the above measurements should be made—this is a subject for our Standards Committee to thrash out.

If we were to adopt a politician's attitude instead of our engineering outlook, we would say, "Why we can't adopt any of this—our equipment doesn't meet all these requirements." The Standards Committees and the Definitions Committees can lower the above suggested values, and if this still does not suffice, we can add MF for medium fidelity, LF for low fidelity, and finally, but not least, VLF for very low fidelity!

Seriously, again, it is suggested that we, as engineering representatives of our industry, are bound to define our boundaries and qualify our terms. *If we don't somebody else will, and soon.*

BOOK REVIEW

Good Listening

R. D. DARRELL, Alfred A. Knopf, New York, 1953, $3.00.

Good Listening, by long-time listener Robert D. Darrell, is an intelligent and persuasive achievement. As a presentation of the joys of participative listening, it will be both stimulating and reassuring to the novice listeners to whom it is directed, as well as rewarding perhaps to old listeners who need a new stimulant!

The first part of the book is devoted to explaining the nature of classical music in terms meaningful to those who may be approaching this particular portion of the world of music from the realm of the popular tune or the middle ground of the "standard" work, and to encouraging the beginning listener by means of a discussion of the basic identities of all music toward a creative enjoyment of the whole complex, ardent grandeur of the most universal of the arts.

The second section of the book is an illuminating and remarkably concise survey of Western musical history, with heavy emphasis on the names of composers representative of each musical period. Darrell disclaims, rightly, any attempt to present a formal history of the subject and prefers to fasten his, and his readers', attention on the makers of music and their works. Only four books are suggested for further reading, all of them historicophilosophical. Although these are sufficient for background, this reviewer-listener felt that mention of one or two of the many books about music itself, such as Philip Goepp's *Great Works of Music*, might have offered an interesting viewpoint via descriptive musical analysis without unduly dissipating the attention or distorting the perspectives of reader-listeners. However, it is certain that interest is sufficient to stimulate most people to a further search for knowledge!

The third and final portion of the book, titled "One World—Many Mansions," deals with music itself, its various forms, its development and interrelation, and the participative role which the listener should play if he is to reap maximum enjoyment and satisfaction from his listening.

An Index-Discography collates the many references to composers and compositions appearing in the text. With a very few exceptions all record references are to long-playing records. Despite the existence on 78-rpm records of a vast number of fine, and in many cases unsurpassed, interpretations, it seems wise to have confined the record index to a single, easily available, and current medium, in which the catalog listings include, by this time, virtually all the standard repertory, many well-known compositions never before recorded, a rapidly increasing inventory of little-known works, and material of historical interest.

It is freely admitted that the list was not meant to be definitive; and although at best a selection may reflect the author's, or a critic's "best" judgment, at worst the selection will serve a presentational purpose until the listener may find for himself a more satisfactory version. It is further noted that the long-playing repertory is growing so fast that any statements as to its scope have only a very temporary value.

It is stressed throughout the book that response to music, to interpretations, and to particular styles of presentation is largely a matter of individual personal taste and preference and should not be regimented by professional opinion any more than necessary. This insistence on the validity of each individual listener's responses and judgments, coupled with a persuasive invitation to the listener to form and maintain his own perspective, is without doubt the major contribution, in fact the primary intent, of the book. It is an approach eminently sensible and refreshingly welcome in a world where the dictum of the authority, supported by a tonnage of predigested opinion, seems increasingly to intimidate the validity of individual expression. The arts, at least, should remain free from regimentation and no less from the ill-advised and selfish purpose of the intellectual initiate who would restrict the understanding of these creative fruits of our culture to those whose background and understanding is deemed suitable for proper empathy with such higher experiences. Discounting the abstruse experiments of the avant-garde, the arts are a common heritage and a common means of communication belonging equally to us all and are no less comprehensible to one than to another.

Of all the arts, music most directly communicates at the emotional level: there are no language barriers, no regional barriers to hinder communication to the most diverse of men a common ecstasy, a common understanding, and a community of laughter. Let us support such a thing and enlarge if we can the area of our community—by good listening.

JOHN H. BEAUMONT
Audio & Video Recording Company

AES NEWS

Notice to Members

The annual election of officers of the Audio Engineering Society will take place on September 2, 1954.

Although reference to this may seem premature, it is customary and proper at this time for the Nominations Committee to learn the preferences of the members relative to individuals whom they feel merit the consideration of the Committee as nominees for the various offices.

Suggestions for the following officers are in order:

President
Executive Vice-President
Central Vice-President
Western Vice-President
Secretary
Treasurer
Three Governors

Your interest in the above will provide the Nominations Committee with information which is essential in maintaining a representative cross section of officers.

Should you wish to *nominate* a candidate, Article VI of the by-laws reads:

"Any voting member in good standing by letter to the Secretary not less than 60 days prior to election date may propose and nominate a candidate, and the name of any eligible candidate so proposed by 10 members shall be entered on the Ballot."

Mail suggestions to Audio Engineering Society, L. J. Scully, Chairman, Nominations Committee, 62 Walter St., Bridgeport 8, Connecticut.

L. J. Scully
Chairman, Nominations Committee
December 31, 1953

Appointments to Committees Announced

The Governors of the Society have announced the following appointments of members to head the Society's committees. The addresses of the chairmen of the committees are included so that members desiring to discuss committee activities or to participate in committee work may communicate directly with the chairmen.

Committee	*Chairman*
Admissions	Price E. Fish Columbia Broadcasting System Engineering Dept. 485 Madison Avenue New York City
Awards	F. Sumner Hall 500 Old Sunrise Highway Amityville, New York
Convention	A. A. Pulley Manager, Recording Division Radio Corporation of America RCA Victor Division 155 E. 24th St., New York City
Constitution and By-Laws	V. J. Liebler Columbia Records, Inc. 799 Seventh Ave. New York City
Cooperative Research	Hugh Knowles Industrial Research Products Inc. 9400 Belmont Ave. Franklin Park, Illinois
Education	Robert Rose Newark College of Engineering Newark, N. J.
Employment Register	C. G. McProud Radio Magazines Inc. Mineola, Long Island, N. Y.
Finance	C. R. Sawyer 16 Blackburn Place Summit, New Jersey
Historical	C. A. Rackey National Broadcasting Co. RCA Building, Radio City New York City
Lecture Course	Julius Postal 435 Warwick St. Brooklyn, New York
Membership	Oliver Read Radio News Ziff-Davis Publishing Co. 366 Madison Ave. New York City
Nominations	Lawrence Scully Scully Machine Co. Walter and Green Sts. Bridgeport, Connecticut
Papers Procurement	Avery Lockner Sound Horizons Inc. 113 West 57th St. New York City
Public Relations	W. O. Stanton Pickering and Company Oceanside, New York
Publications	Richard H. Ranger Rangertone, Inc. 73 Winthrop Street Newark, N. J.
Sections	C. J. LeBel Audio Instrument Co. 133 W. 14th St. New York City
Standards	Wm. H. Offenhauser, Jr. Box 595 New Canaan, Conn.

Journal Publication Policy

The *Journal of the Audio Engineering Society* is entering its second year of publication and is planning to expand its services to members in the coming year. In order to make the *Journal* of greater value, the Editors are desirous of obtaining more technical papers on *all* phases of audio, including telephone communications, hearing aids, instrumentation, broadcast facilities, and control systems.

Notes on the preparation of material for publication are available from the Office of the Editor. However, two important rules are reprinted below.

"All copy must be double or triple spaced typewritten material."

"All illustrations should be either large glossy photographs or India ink line drawings. Reproduced copy *cannot* be used."

Material published in the *Journal* may be reprinted in magazines or privately with permission of the Editor and the author of the paper. Thus the *Journal* may be of greater value in providing the widest possible dissemination of competent audio engineering papers.

News items concerning AES members should be sent to the Editor, P. O. Box 12, Old Chelsea Station, New York 11, New York.

Audiology Course

The Los Angeles State College of Applied Arts and Sciences believes it is the only college to offer a Bachelor of Science degree in audiology. This program was originally planned to qualify personnel for service in audiology clinics (speech and hearing), in otologists' offices, in the fitting of hearing aids, and as school audiometrists. However, with the recent developments in the field of hearing, it hopes to expand the program to include courses for those interested in audio engineering and those concerned with the problems of noise and noise control. The basic courses such as audiology and audiometry are offered each semester in evening or on alternate semester basis, depending upon the demand for any particular course. In the present courses extensive use is made of several makes and models of audiometers, various types of testing equipment, and the artificial ear. In addition to the Bachelor of Science degree in audiology, the college also gives certificates of successful completion to those students who satisfactorily complete prescribed sequences of courses. The college itself was established in 1949 primarily to serve business and industry in the Los Angeles region, and offers only junior, senior, and graduate level work. It is located on the campus of the Los Angeles City (Junior) College, which provides work in the lower divisions.

AES Lecture Course

The Lecture Course Committee of the AES announces a series of lectures entitled "Engineering the Home Music System." The lectures, scheduled to begin around the end of February, will deal on an engineering level with the theoretical and practical aspects of designing, building, and hooking up wide-range audio systems for the home.

The series will be available to members of the AES and to the public at a nominal fee. Details will reach members through the mails.

High Fidelity Interest Grows

The year 1953 saw widespread changes in the audio field. The term "high fidelity" was taken into virtually every home in the country through newspapers, magazines, radio and television programs, and commercial advertising. For a number of years "high fidelity" has been sought by comparatively few, although each year brought more into the fold. It was spurred on by those listening to friends' home-installed sound systems, by manufacturers plugging custom tuners and component parts, by increasing press coverage of audio fairs, and by an increasing number of high-fidelity records put out by record companies.

This was pointed out recently in a National Association of Radio and Television Broadcasters *Member Service Bulletin,* FM Department. They remind that "what FM started out to promote in the early days is suddenly taking fresh hold on public interest," and that the "best high-fidelity radio must be FM radio." With the record business swinging to more high-fidelity records, demand for better-quality audio equipment at reasonable prices and in attractive packages has been increasing steadily. "High fidelity" was taken over by old-line receiver manufacturers this past year, accompanied by grand-scale advertising. "High fidelity" has arrived!

A news note in *Wall Street Journal* of November 20, 1953, indicates the scope of high-fidelity coverage. The quote, which follows, refers to a subject of frequent argument among engineers:

"Defining 'Hi-Fi' phonographs is the aim of a special industry committee, set up at Federal Trade Commission behest. F. T. C. thinks the 'high fidelity' label is subject to 'misuse'—applied to sets whose 'fi' isn't very 'hi.' But the Commission can't spank companies using the term loosely until the industry group decides what it means."

Japanese Section Formed

The Governors of the Society have announced the admission of a Japanese section having 37 members. This is the first section formed outside the United States, and it is hoped that it will be the first of many such sections. Members in other countries desiring to form a section are invited to communicate with the Chairman of the Sections Committee, C. J. LeBel, P. O. Box 12, Old Chelsea Station, New York 11, New York.

Section Meetings

Cincinnati

Chairman: Harvey B. Glatstein
Secretary: William J. Mahoney, 1730 Kleemeier St., Cincinnati 5, Ohio
Paper: "A High Quality, Wide Range Ceramic Cartridge," Mr. Fritz Wood, Electro-Voice, Inc., December 2, 1953.

Columbus

Chairman: J. E. Anderson
Secretary: William E. Parker, 1271 Republic Ave., Columbus, Ohio
Papers: "Stereophonic Sound," Russell Tinkham, Ampex Electric Corp., October 9, 1953.
"Wanna Buy A Record?" Mel Blanc, Capitol Records, Inc., November 19, 1953.

Los Angeles

Chairman: Richard F. Hastings
Secretary: Herbert E. Farmer, 7826 Dunbarton Ave., Los Angeles 45, California
Papers: "What About the Ear and Hearing?" Dr. Howard House, Professor of Otolaryngology, University of California, October 27, 1953.
"Chassis Design and Layout," Richard Hoskin, Berlant Associates, November 24, 1953.
"Audiometer Testing," Dr. Helen Kennedy, Los Angeles State College, November 24, 1953.

New York

Papers: "Twenty-Four Hour Dual-Channel Magnetic Tape Recorder," Morris L. Groder, Bureau of Aeronautics, Navy Dept., September 15, 1953.
"Some Recent Developments in the Multiplex Transmission of Frequency Modulated Signals," Edwin H. Armstrong, Columbia University; John H. Bose, E. H. Armstrong; October 13, 1953.
"Tracking, Resonance and Distortion," Reuben Carlson, Fairchild Associates, December 15, 1953.

San Francisco

Chairman: B. H. Smith
Secretary: Wallen W. Maybeck, 2751 Buena Vista Way, Berkeley 8, California
Paper: "Design and Performance of Detector Circuits," Bob H. Smith, Radiation Laboratory, University of California, November 9, 1953.

RENSSELAER POLYTECHNIC INSTITUTE

Chairman: Charles R. Wood
Secretary: John D. McKendree, 2226 Burdett Ave., Troy, N. Y.
Papers: "A Home Music System," Gus Coutsourakis, student, November 3, 1953.
"Small Speaker Enclosures," Dominick Vicedomine, student, November 3, 1953.

New Members

Honorary Member

Wente, E. C., Bell Telephone Laboratories, Inc., Murray Hill, New Jersey

Members

Adelman, Arthur Zachary, 25 Chittenden Ave., New York 33, New York
Bishop, J. D., 160 Summit Ave., Summit, New Jersey
Bogen, Lester N., 579 Fairway Drive, Woodmere, New York
Bohn, William Chanler, 45 East 85th St., New York 28, New York
Capps, William Lloyd, 1925 Chatham Ave., Charlotte 5, North Carolina
Clark, Philip B., 309 Euclid Ave., Syracuse 10, New York
Cohen, Robert I., 46 West 17th St., New York 11, New York
Collins, Benjamin Franklin, Jr., 7353 West 82nd St., Los Angeles 45, California
Dimmick, Henry M., 230 West Penn St., Butler, Pennsylvania
Douglas, John Creighton, Apt. 4, 80 Hudson Ave., Montreal 16, Canada
Edelman, Robert D., 1008 Remington Rd., Philadelphia 31, Pennsylvania
Edwards, Lon, 16 Lawncrest, Danbury, Connecticut
Greenblatt, Stanley, Microwave Research Institute, Polytechnic Institute of Brooklyn, 55 Johnson St., Brooklyn 1, New York
Hastings, Theodore Mitchell, Jr., 171 Newbury St., Boston 16, Massachusetts
Hill, Don G., 308 Central Ave., Needham 94, Massachusetts
Hof, Zygmunt N., 1 West 89th St., New York 24, New York
Jacobs, Bernard, 4000 Washington Blvd., Chicago 24, Illinois
Jamroz, Anthony, 188 King St., London, Ontario, Canada
Johns, Nicholas Harry, 76 Westville Ave., Danbury, Connecticut
Justus, Emery, 3235 Ridgewood Ave., Montreal, Quebec, Canada
Kabrick, Wallace Jackson, Plainville, Illinois
Keim, Peter M., 725 South LaSalle St., Chicago 5, Illinois
Knap, Henry Beemer, 44 Rosebury Rd., Toronto 10, Ontario, Canada
Lambert, Robert C., 121 Seacord Road, New Rochelle, New York
Lindridge, Charles D., 10 Rockledge Road, Montclair, New Jersey
Lorenz, Howard Herman, 1126 Union, Benton Harbor, Michigan
Metzger, William, 269-11 79th Ave., New Hyde Park, New York
Nagato, Kunio, 583-3 Higashi-Magome-cho, Otaku, Tokyo, Japan
Nakamura, John Hisatsugu, 29 Iigurakatamachi Azabu, Minato-ku Tokyo, Japan
Newins, Harold S., Rt. Box 23, Red Bluff, California
Nunn, Ewing D., Saukville, Wisconsin
Pares, Octavio, 442 Main St., Paterson, New Jersey
Perelman, Ira B., 28 Windermere Drive, Yonkers, New York
Roberts, George A., 409 College Ave., Swarthmore, Pennsylvania
Rousseau, Maurice, 1191 Mountain St., Montreal, Canada
Vesa, Eugenio, Calzada No. 164, Vedado, Havana, Cuba
Wagner, Robert E., Box 1184, Bethlehem, Pennsylvania
Weinberg, Harold Meyer, 200 Avon Road, Upper Darby, Pennsylvania
Williams, Alfred R., 390 Eglinton Ave., Toronto 12, Canada
Woods, James William, 16 Athlone Rd., Toronto 6, Ontario, Canada

Associate Members

Baunach, Edward L., 2 Westminster St., Massapequa, New York
Boswell, Ian I., Crawley Grange, Newport Pagnell, Buckinghamshire, England
Brooks, Joseph H., 17551 Santa Rosa Drive, Detroit 21, Michigan
Clapper, Harold Thomas, 8006 Aberdeen Road, Bethesda 14, Maryland
Cox, Edwin Clement, Jr., 1202 Ryland Ave., Cincinnati 37, Ohio
Cunliffe, Arthur, 2531 Cedar Drive, Baltimore 7, Maryland
Dancy, Roy Wallace, NAVY 926 Box 51 Shop X67 c/o F. P. O. San Francisco, California
Davis, George Webster, 5259 East Beverly Blvd., Los Angeles 22, California
Dwyer, Raymond J., 153 Washington Ave., Rochester 17, New York
Ehrlich, Joel, 8860 19th Ave., Brooklyn 14, New York
Forristal, James A., 1905 Hedges, Independence, Missouri
Frey, Martin M., R.D., Columbia, New Jersey
Gellman, Ernest S., 312 West 48th St., New York 19, New York
Gotthardt, Charles John, 4627 Los Feliz Blvd., Los Angeles 27, California
Gutwirth, Albert, 16 East 71st St., New York 21, New York
Hallmark, C. E., 2 Werling Road, New Haven, Indiana
Heiderbrecht, John, 301 Church Road and Grantham Tnp., St. Catharines, Ontario, Canada
Hogue, Ephraim Walters, 6505 Persimmon Tree Rd., Bethesda, Maryland
Humphries, Jack H., 1812 Baltic Ave., Virginia Beach, Virginia
Kenly, William Purnell, 704 North Monroe St., Arlington 1, Virginia
Kilpatrick, David G., 3527 Indian Queen Lane, Philadelphia 29, Pennsylvania
Langmuir, Dean Bruce, Biophysics Division, Naval Medical Research Institute, N.N.M.C., Bethesda, Maryland
Leland, Ronald F., 1472 Thomas Barbour Drive, EauGallie, Florida
Lintz, Larry M., Big Springs, Nebraska
Lucia, Raymond H., c/o WHAM-FM-TV, Rochester Radio City, Rochester, New York
McCarty, Walter Richard, 2710 North 26th St., Lawton, Oklahoma
Macomber, Thomas W., 206 Jordan Court, Los Altos, California
Martel, Joseph Sully, Jr., 30 Clark St., Lodi, New Jersey
Medicus, Emil Ragland, 132 Sparger Rd., Bristol, Tennessee
Oseth, John Marcus, U.S.S. Norfolk (EDL-1), Fleet Post Office, New York, New York
Petschauer, Frederick John, 112 Rockwell Ave., Long Branch, New Jersey
Rhodes, Dr. Bernard L., P.O. Box 314, Belvedere, California
Scott, Robert Francis, P.O. Box 411, Bay Shore, New York
Smyth, Rossney E., 351 West 71st St., New York 23, New York
Sogge, Ralph H., 3910 Everett, Lincoln 2, Nebraska
Steeb, Edgar Charles, Jr., 15 Groveland Ave., Buffalo 14, New York
Stone, George Thomas, Jr., 4010 Nicholson St., Hyattsville, Maryland
Tasto, John, 11 Maple St., Bloomfield, New Jersey
Vesser, William C., 5000 Blanco Ave. Apts., El Paso, Texas
Wise, Marvin F., 45 Fairlawn Ave., Albany, New York
Zacharellis, George, 23 Avenue C, Bayonne, New Jersey
Zale, Ben, 1454 Grand Concourse, Bronx 57, New York

Student Members

Biggar, Robert A., 96 Temple St., West Roxbury, Boston, Massachusetts
Clark, George Howard, 31 16th Ave., Columbus 1, Ohio
Cooley, John Alden Xavier, Room 121, Dorm D, Rensselaer Polytechnic Institute, Troy, New York
Edelbaum, Philip Roger, 41 Alden Court, Malverne, New York

Gicca, Francis Alexander, 2166 14th St., Troy, New York
Glassman, David M., Room 306, Dorm D, Rensselaer Polytechnic Institute, Troy, New York
Goings, Richard Arthur, 4325 Latona, Seattle, Washington
Grothe, Alain, 5611 Darlington St., Montreal 26, Quebec, Canada
Harmon, Leon D., Box 382, Kingston, New Jersey
Hill, Thomas W., Clement Dorm, Rensselaer Polytechnic Institute, Troy, New York
Lieberman, Julian L., 1762a East 3rd St., Brooklyn 23, New York
McClure, George Franklin, 1305 N.W. 3rd Ave., Gainesville, Florida
Maner, Marion Fitch, Jr., Southern Technical Institute, Chamblee, Georgia
Perry, Peter B., Room 331, Bldg. D, Rensselaer Polytechnic Institute, Troy, New York
Puttre, Robert E., 111-30 121st St., South Ozone Park 20, New York
Rubin, Llewellyn Adam, Box 76, University of Pennsylvania Dorms, 37th & Spruce Sts., Philadelphia, Pennsylvania
Samson, Stephen Louis, Waite Dormitory, Sage Ave., Rensselaer Polytechnic Institute, Troy, New York
Shao, Eugene B., Room 211, Bldg. B, Rennselaer Polytechnic Institute, Troy, New York
Smith, Oliver J., III, 531 Burrowes Ave., Lancaster, Pennsylvania
Vicedomine, Dominick Anthony, 2328 3rd Ave., Watervliet, New York
Vroom, William Lee, Church I, Rensselaer Polytechnic Institute, Troy, New York

Change of Grade

Fellow:
Chinn, Howard A., R. R. No. 2, New Canaan, Connecticut
LeBel, C. J., 370 Riverside Drive, New York 25, New York
Rackey, C. A., P. O. Box 564, Westport, Connecticut
Roys, H. E., 300 Third Avenue, Haddon Heights, New Jersey

Member:
Newman, Aaron J., 1127 East 39th Street, Brooklyn 10, New York
Seeley, John R., 1455 Sheridan Ave., New York 57, New York

Associate:
Manno, Robert, 780 Riverside Drive, New York 32, New York
Smith, Remy Joseph, 124 Hickory Grove Drive, Larchmont, New York

Deceased Members

It is with regret that the Society has been notified of the death of two of its members, J. B. Abernathy, Jr., and Hideo Yamaguchi.

JOURNAL AUTHORS

WILLIAM F. BOYLAN was born in 1925 in Ardmore, Oklahoma, and received his formal education at the University of Idaho and Northwestern University, where his fields of special study were education and mathematics. During World War II he was a member of the Armed Forces, and in 1948 he joined the staff of DeForest's Training School as instructor in electricity and mathematics. In 1950 Mr. Boylan joined Magnecord, Inc., as an electrical engineer, and at the present time he is senior electrical engineer on commercial products.

WILLIAM E. GOLDSTANDT was born in 1927 in Kansas City, Missouri. He attended Purdue University from 1944 to 1949, where he received a B.S. in mechanical engineering with special studies in machine design. Serving with the U. S. Navy during World War II, he received training in the Radio Materiel School program. After graduation from Purdue, Mr. Goldstandt accepted a position with the Sheldon Lathe Company, of Chicago, where he was engaged in mechanical design and production liaison activities. In 1951 he joined the engineering staff at Magnecord, Inc. where as senior mechanical engineer he has been responsible for most of the mechanical design work. His most recent work has been the design of the tape transport unit for the new Magnecord professional recorder.

LOUIS S. HOODWIN

CALVIN M. HOTCHKISS

LOUIS S. HOODWIN was born in 1925. He attended Northwestern University where he majored in physics and received his B.S. degree. After his graduation he joined Electro-Voice, Inc., Buchanan, Michigan, where he is working as a loudspeaker design engineer. Mr. Hoodwin is an associate member of the Acoustical Society of America.

CALVIN M. HOTCHKISS was born in Rochester, New York, in 1921. He attended Princeton University as a pre-med student with a major in French and Italian, receiving his A.B. degree in 1943. He enlisted in the U. S. Army Reserve in 1942 and was inducted in 1943. From 1945 to 1948 he was a head chemist at Chas. R. Phillips Co., Flavor Division of General Foods Corporation. Then in 1948 he went to the University of Rochester as an instructor and graduate student in romance languages and literature, receiving his M.A. degree in 1949. From there Mr. Hotchkiss went to France where he studied at École du Louvre, Institute des Sciences Politiques, and the University of Paris (Sorbonne), and received a degree in literature at the Sorbonne. During this period he also held the position of chemist and research testing engineer at Kodak-Pathé, Vincennes. In 1950 he won a competitive scholarship to Yale with a fellowship for Ph.D. study in comparative European languages and literature. However, Mr. Hotchkiss decided, instead, to go to the Motion Picture Film Division of Eastman Kodak Company in New York City, where he is at present. He is a member of the SMPTE.

ARTHUR W. KELLY, JR.

ARTHUR WILLIAM KELLY, JR., was born in New York City in 1926. He received his degree in management engineering in 1951 from Rensselaer Polytechnic Institute, where he minored in electrical engineering. Upon graduation, he accepted a sales engineering position with Motorola, Inc., in the two-way communications division. In 1952, he accepted his present position with the Photocircuits Corporation.

W. H. OFFENHAUSER, JR.

JULIUS B. POSTAL

WILLIAM H. OFFENHAUSER, JR. was born in Brooklyn, New York, in 1904. He received his A.B. degree, with engineering option, from Columbia University in 1929. From there he went to the engineering department of RCA Photophonesound films. In 1933 he was a contractor to the Army Pictorial Service, Signal Corps. From 1936 to 1939 he was associated with J. A. Maurer, Inc., and from 1939 to 1943 he was vice president and member of the board of directors of J. A. Maurer and manager of Precision Film Labs. During 1942 and 1943 he was also a project engineer working on the proximity fuse project at Johns Hopkins University. The next year, Mr. Offenhauser was consultant for the Signal Corps Photo Center and chairman of the Photo Subcommittee Tropic Deterioration project, National Defense Research Committee, at Washington. During 1946 and 1947 he was a consultant on film projection in color television for Columbia Broadcasting System. Then he worked on a research project for Cornell University Medical College, for the U. S. Public Health Service, that took him into Africa recording mosquito sounds. Currently, Mr. Offenhauser is an independent consultant on films and television.

A Fellow of the SMPTE and the Radio Club of America, Mr. Offenhauser is also a member of the AES, the Acoustical Society of America, AAAS, and the Science Film Assn., London. He is on the board of directors of the Radio Club of America, and chairman of the board of managers of the SMPTE. Mr. Offenhauser has written a number of scientific articles and books and holds both U. S. and foreign patents.

JULIUS BERNARD POSTAL was born in New York City in 1915 and received his B.A. degree in English literature from Brooklyn College in 1937. From 1934 to 1939 he worked as news editor, newscaster, announcer, and producer of special events programs for a number of small radio stations. In 1941 Mr. Postal joined the staff of the American Museum of Natural History, New York City, remaining with them until 1947. While there he held various positions including science script writing, chief of all science broadcasting, consultant to the division of audio-visual aids, consultant to the Museum's scientific staff on motion picture equipment problems and sound recording. The latter led him into participation in several research projects involving synchronous recording of sound and motion pictures in the field. From 1947 to 1952 Mr. Postal was supervisor of production at Tele-Science Productions, New York City, producers of 16 mm educational and scientific films. Subsequently, in 1952 and 1953, he worked as a technical writer with a New Jersey engineering firm specializing in electronic analogue computers and wide-band magnetic drum storage systems, and also with a New York publishing firm. Currently, he is again associated with Tele-Science Productions.

Mr. Postal, the author of a number of magazine articles, is a member, active grade, of the SMPTE and serves on their Interim Committee on Nomenclature. He is also a member of the AES, currently chairman of their Lecture Course Committee, and holds membership in the Metropolitan New York Audio-Visual Association.

FRANK RADOCY was born in Stamford, Connecticut, in 1921. In 1939 he was employed by Audio Devices, Inc., as a laboratory technician and has remained with that company to date, with the exception of four years spent in the Army Air Corps during World

War II. He spent three years attending special evening courses in electronics and radio at The Wright Technical and Bridgeport Engineering Institutes. In 1946 he was made manager of the lacquer department, and in 1949 he was appointed to his present position as director of quality control. His main interests lie in the testing and development of magnetic tapes and lacquer recording disks.

HERMON HOSMER SCOTT

HERMON HOSMER SCOTT was born in Somerville, Massachusetts, March 28, 1909. He received the degrees of B.S. and M.S. in electrical engineering from the Massachusetts Institute of Technology in 1930 and 1931, respectively. From 1931 to 1946 he was associated with the General Radio Company, first as sales engineer and development engineer and later as executive engineer in charge of audio frequency, acoustic, broadcast and related developments. From 1947 to date he has been president and director of engineering of Hermon Hosmer Scott, Inc., Cambridge, Massachusetts. Mr. Scott is a Fellow of the Audio Engineering Society, the IRE, and the Acoustical Society of America, and a member of the AIEE. He is the author of numerous technical papers on the measurement and reproduction of sound and related laboratory measuring equipment and holds both United States and foreign patents in these fields. He is the inventor of the dynamic noise suppressor and the common type of RC oscillators and RC selective circuits. His designs for sound level meters and associated equipment have won several awards. In 1951 he was presented with the John H. Potts Memorial Award by the Audio Engineering Society "for outstanding achievement in the field of audio engineering." Mr. Scott and his organization have also been engaged in research and development for the U. S. Navy, including the development of specialized sound measuring and analyzing apparatus.

WALTER T. SELSTED was born in Berkeley, California, in 1921. He is a graduate of the University of California, 1944, in electrical engineering. From 1944 to 1946 he was engaged in research on classified projects on nuclear physics at the Manhattan Project Radiation Laboratory at the University of California. From 1946 to 1949 he was chief engineer in FM broadcasting station, with the Pacific Broadcasting Company. Since 1949, Mr. Selsted has been with Ampex Corporation where he is engaged in research, design, and development on mechanical and electronic principles applicable to magnetic recorders for high-fidelity sound reproduction and instrumentation.

Mr. Selsted is the inventor of three electronic circuit patents, assigned to the U. S. Government (University of California). In addition, he has applied for patents on numerous components, features, and systems of magnetic recording apparatus, such as special drives, automatic synchronization equipment, and multichannel head assemblies. Mr. Selsted is a member of the AES.

ROBERT D. WINSTON

ROBERT D. WINSTON was born in 1921 in Milwaukee, Wisconsin. He attended the University of Wisconsin and Marquette University and holds the degree of B.S. in electrical engineering. He then joined Cinemart, Inc., as chief engineer for recording studios, and his work included design and installation of the studios and supervision of operations. From there Mr. Winston went to Langevin Manufacturing Corporation. His activities at Langevin included sales engineering involving the audio equipment produced by this company for broadcasting stations, recording studios, government requirements, and industrial use. He is now engineering representative for the standard products division of the Audio and Video Products Corporation. Mr. Winston is a member of the AES.